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DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
JOSEPH A. HOLMES, DIRECTOR

OCCURRENCE OF EXPLOSIVE GASES IN COAL MINES

BY

N. H. DARTON

[The investigations of the occurrence of gas in coal mines in southern Illinois were conducted under a cooperative agreement with the department of mining engineering of the University of Illinois and the Illinois State Geological Survey]

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CONTENTS.

Page.
Introduction 11
The gases in coal and the conditions controlling their escape 12
General considerations 12
Character of mine gases 13
Methane 13
Carbon dioxide 13
Carbon monoxide 14
Nitrogen and oxygen 14
Fire damp 14
Nature of gases in coal beds 15
Composition of blower gas 16
Gas from English blowers 16
Gas from Austrian mines 17
Gas from Prussian mines 17
Gas from bore holes in anthracite region, Pennsylvania 18
Gas from French mines 19
Conditions under which gas is given off by coal 19
Occurrence of "blowers" or "feeders" 20
Occurrence of gas outbursts 21
Causes 21
Instances of serious outbursts 21
Three Pennsylvania mines 21
Two Belgian mines 22
Morissey, B. C 22
Abercarne mine, Wales 22
Crushed coal a cause of gas outbursts 22
Discussion of outbursts in Belgian coal fields 23
Outbursts in Agrappe, Produits, and Marcinelle-Nord mines 23
Investigations of Stassart and Lemaire 24
Outbursts due to roof fall or movement of face 25
Gas from squeezes 26
Methane in coal 26
Origin 26
Relation to class of coal and metamorphism 27
Condition of methane in coal 28
Relation of methane to age of coal 29
Relation of methane to depth of coal 29
Relation of methane to structural features 30
Relation of methane to character of cover 31
Diffusion of methane 31
Gases in coal samples 32
Gas from samples of English coals 32
Gas from samples of German coals 33
Gas from samples of Belgian coals 34
Gas from samples of American coals 35

The gases in coal and the conditions controlling their escape—Continued. Page.
- Rate of escape of gas from coal 36
  - Effect of crushing 36
  - Rate of escape from lump coal 37
  - Rate of escape from pulverized coal 39
  - Comparative tests of different sizes 40
    - Method of testing 40
    - Conclusions 41
  - Variation in volume from different coals 42
    - Tests of various American coals 42
      - Method of testing 42
      - Results of tests 43
    - Tests of Illinois coals 45
  - Effect of oxidation 46
- Amount of methane in mine air 48
  - Factors affecting volume 48
  - Percentages in Prussian mines 49
  - Percentages in Austrian mines 50
  - Percentages in Russian mines 51
  - Percentages in mines of Scotland 51
  - Relation of volume of methane to amount of coal mined or exposed 52
    - Investigation in Saarbrücken basin, Germany 52
    - Emanation from mines near Wilkes-Barre, Pa 52
    - Emanation from mines in Saxony 52
    - Results of Austrian investigation 53
    - Emanation from Prussian mines 54
    - Emanation from a mine at Liévin, France 56
    - Daily variations in methane emanation 58
      - Winkler's investigations 58
      - Tests of Prussian commission 58
      - Tests by Hilt 58
      - Tests by Liveing 60
- Pressure of gas in coal beds 60
  - Gas pressure in coal beds in England 61
    - Method of conducting tests 61
    - Results obtained 62
    - Mallard's view of Wood's observations 63
  - Gas pressure in coal beds in Wales 64
  - Gas pressure in coal beds in Belgium 64
    - Investigations of Schorn, Watteyne, and Maquet 64
    - Tests by Maquet 67
    - Conclusions from results of pressure tests in Belgium 69
  - Gas pressure in coal in Liévin mine, France 69
    - Tests in Frederic bed 70
    - Tests in Alfred bed 70
    - Tests in Leonard bed 71
  - Gas pressures in coal at St. Étienne 72
    - Results of tests 72
    - Conclusions 73
  - Gas pressure in coal in Austrian mines 73
- Volume of gas from holes in solid coal 73
  - Tests at St. Étienne 73
  - Tests at Liévin 74
  - Tests by Wood in English mines 74
- Effect of rock and water pressure on gas pressure in coal 75

The gases in coal and the conditions controlling their escape—Continued.

Page.
Permeability of rocks and coal to gas.. 76
  Escape of gas from strata near Wilkes-Barre, Pa........................ 76
  Escape of air from sealed chamber in Maryland mine.................. 77
  Gas in strata adjoining the coal.. 78
    Gas in a sandstone stratum in Pennsylvania........................ 79
Relation of volume of gas to underground temperature.................. 80
Coal oxidation as a source of gas.. 80
  Increase in temperature from oxidation................................ 80
  Absorption of oxygen by coal samples................................. 81
Effects of variation of atmospheric pressure on gas emanation............ 81
  Investigations in British mines... 83
  Investigations in Prussian mines....................................... 84
    Tests by Hilt near Aix-la-Chapelle and Karwin........................ 84
        Review of Hilt's work by Mallard and Le Chatelier.............. 86
  Investigations in Austrian mines.. 86
    Tests by Koehler at Karwin, Aachen, and Hibernia..................... 86
    Conclusions by Behrens... 88
    Tests at Hanover mine.. 89
    Investigations of the Austrian Fire Damp Commission................ 90
  Investigations in French mines.. 90
    Tests at Liévin... 91
      Atmospheric conditions in old workings............................ 92
      Relation of barometric pressure to amount of gas from fresh coal surfaces.. 94
      Effect of settling of roof and floor................................. 95
      Relative volumes from different workings under various conditions. 95
      Conclusions derived from results of tests at Liévin................ 97
  Observations in England and the United States........................ 97
    Tests with samples of Pennsylvania coal.............................. 98
Effects of earth movements on methane emanation......................... 98
Duration of methane emanation from coal................................. 101
Gas drainage in mining.. 101
Relation of methane content to character of coal........................ 102
Probable error in figures for methane content in mine air............... 103
Explosive gas in the northern anthracite coal field of Pennsylvania....... 104
Introduction.. 104
General structure of the northern anthracite basin...................... 106
Collection of mine-air samples... 107
Conditions in representative mines....................................... 108
  Lance mine.. 108
    Succession and structure of beds..................................... 108
    Return-air samples.. 109
    Red Ash returns... 110
    Ross returns.. 111
    Bennett returns... 112
    Cooper returns.. 114
    Five-foot returns... 115
    Hillman returns... 116
    Résumé of conditions in Lance mine................................... 117
      Methane outflow from Hillman and Five-foot beds................... 118
      Outflow from Cooper and Bennett beds.............................. 118
      Outflow from Ross and Red Ash beds................................ 119
      Generalizations as to methane emanations.......................... 119
    Influence of river deposits... 121

Explosive gas in the northern anthracite coal field of Pennslyvania—Continued.
  Conditions in representative mines—Continued. Page.
    South Wilkes-Barre mine 122
      Return-air samples 122
      Air samples from the Abbott returns 123
      Air samples from the Hillman returns 125
      Résumé of conditions in South Wilkes-Barre mine 126
    Dorrance mine 127
      Succession and structure of beds 128
      Return-air samples 128
      Air samples from Red Ash returns 129
      Composition of Red Ash coal 130
      Air samples from Baltimore returns 131
      Air samples from Five-foot returns 132
      Air samples from Hillman returns 132
      Résumé of conditions in Dorrance mine 133
    Hoyt mine 134
      Air samples from Red Ash returns 134
        Résumé of conditions in Red Ash workings 136
    Mine No. 14, near Pittston 137
      Air samples 137
      Air samples from Pittston returns 138
      Air sample from Checker return 138
      Composition of Pittston coal 138
    Sloan mine 139
      Air samples from Dunmore returns 139
      Structure of Dunmore bed 141
      Character of Dunmore coal 142
      Amount of methane in relation to area of coal exposed 142
      Carbon dioxide in mine air 143
      Chance of leakage of gas to higher workings 143
  Effect of cessation of mining on mine air 144
    Results of sampling air of idle mines 144
      Discussion of results 146
        Lance mine 146
        South Wilkes-Barre mine 146
        Dorrance mine 146
        Hoyt mine 147
        Sloan mine 147
      Résumé 147
  Miscellaneous observations in mines in the anthracite field 147
    Mines in and about Scranton 147
      Bellevue and Pancoast mines 148
      Marvine mine 148
      Dickson mine 148
      Green Ridge and Diamond mines 148
      Storrs, Cayuga, and Brisbin mines 149
      Manville and Grassy Island mines 149
    Mines between Pittston and Hudson 150
      Mine No. 6 150
      Pine Ridge mine 150
      Delaware mine 152
    Mines south of Wilkes-Barre 153
      Baltimore No. 5 mine 153
      Cunnyngham mine 154

Explosive gas in the northern anthracite coal field of Pennsylvania—Contd.

Miscellaneous observations in mines in the anthracite field—Continued.

Mines south of Wilkes-Barre—Continued.

Page.
Hollenback mine........ 154
Maxwell No. 20 mine........ 156
Mines near Nanticoke and Hanover........ 157
Auchincloss mine........ 157
Bliss mine........ 159
Truesdale mine........ 161
Mines between Luzerne and Avondale........ 163
Harry E. mine........ 163
Pettebone mine........ 164
Kingston No. 4 mine........ 165
Plymouth No. 2 mine........ 166
Dodson mine........ 167
Nottingham mine........ 168
Avondale mine........ 169
Methane from culm........ 169
Pressure of gas in the anthracite field........ 170
Gas in bore holes in the anthracite field........ 170
Gas conditions in anthracite field compared with those in other American mines........ 172
Some features of fire-damp explosions in the northern anthracite field... 173
Explosive gas in mines in the southern part of the Illinois coal field........ 175
Introduction........ 175
General features of the coal measures in southern Illinois........ 175
Distribution and relation of the coal beds........ 175
Stratigraphy........ 176
Structure........ 177
Character of the coals........ 178
Occurrence of gas in southern Illinois mines........ 179
Conditions in representative mines in Herrin bed........ 180
Mines near Benton........ 180
Hart-Williams mine........ 180
Benton mine........ 181
Hanaford mine........ 182
Mines near Christopher........ 183
United mine........ 183
Zeigler district mine........ 183
Zeigler mine........ 184
Mines near Duquoin........ 185
Paradise mine........ 186
Majestic mine........ 187
Davis mine........ 187
Horn mine........ 187
Mines near West Frankfort........ 188
Dering No. 11 mine........ 188
Dering No. 18 mine........ 190
Wilmington-Star mine........ 190
Mines about Johnston City........ 191
Standard or East mine........ 191
West mine........ 192
Blackbrier mine........ 193
New Virginia mine........ 193

Explosive gas in mines in the southern part of the Illinois coal fields—Contd.
  Occurrence of gas in southern Illinois mines—Continued.
    Conditions in representative mines in Herrin bed—Continued.
      Mines about Johnston City—Continued.

Page.

        Carterville district mine 194
        Oak Ridge mine 194
      Mines northeast of Marion 194
        Colp mine 195
        Scranton mine 195
        West Virginia mine 195
      Mines northwest of Marion 195
        Peabody No. 3 mine 195
        Peabody No. 2 mine 196
        Big Muddy mine 196
      Mines south and west of Herrin 197
        Hemlock mine 197
        Taylor No. 2 mine 198
        Taylor No. 1 mine 199
        Sunnyside mine 199
      Chicago & Carterville Co. mines 199
        "A" mine 200
        "B" mine 200
      Pond Creek, Possum Ridge, and Rend No. 2 mines 201
        Pond Creek mine 201
        Possum Ridge mine 202
        Rend No. 2 mine 202
      Mines north of Carterville 202
        Burr C mine 203
        Madison No. 8 mine 203
        Madison No. 9 mine 203
        C. & B. M. mine 204
      Mines No. 7 and No. 8 of the Big Muddy Coal & Iron Co 204
      Bush and Royalton mines 205
      Hallidayboro mine 206
      Mine at Galatia 207
    Conditions in representative mines in Harrisburg bed 207
      Mines about Harrisburg 207
        O'Gara No. 15 mine 207
        O'Gara No. 7 mine 208
        O'Gara No. 9 mine 208
        O'Gara No. 3 mine 208
        O'Gara No. 12 mine 209
        O'Gara No. 1 mine 210
      Mines near Eldorado 210
        O'Gara No. 10 mine 210
        O'Gara No. 8 mine 211
        Nigger Hill mine 211
    Conditions in representative mines in Murphysboro bed 212
      Mines near Murphysboro 212
        No. 9 mine 212
        Harrison mine 212
        Blair No. 1 mine 213

Explosive gas in mines in the southern part of the Illinois coal field—Contd.

Occurrence of gas in southern Illinois mines—Continued.

Page.

Pressure of gas in coal beds 213
- Method of making test 213
- Tests in Zeigler mine 214
  - First test 214
  - Second test 214
- Test in Hart-Williams mine 215
- Test in Dering No. 11 mine 215
- Test in Dering No. 18 mine 216
- Test in United mine 216
- Tests in Benton mine 216
- Tests in Chicago & Carterville Co. "B" mine 217
- Test in Blackbrier mine 217
- Comparison of results in different mines 217

Variations in volume of gas during mining 218

Effect of cessation of mining on volume of methane 219

Rate of escape of gas from Illinois coal 220

Relation of methane emanation to depth 222

Probable increase of gas in deeper or larger mines 224

Summary of conditions of occurrence of methane 225
- Composition of gas given off by coal 225
- Manner of escape of gas from coal 226
- Pressure of gas in solid coal 227
- Volume of gas in coal 228
  - Outflow at certain mines 229
- Influence of temperature on methane emanation 230
- Influence of composition of coal on gas emanation 231
- Atmospheric influences 231
- Relations of methane accumulations to explosions 232

Selected bibliography 233

Publications on coal-mine accidents and methods of coal mining 238

ILLUSTRATIONS.

Page.

PLATE I. Cross section of the northern anthracite coal basin 106

II. Structural map of the northern anthracite coal basin, showing some conditions of distribution of methane 106

III. Map of part of workings in Abbott bed, South Wilkes-Barre mine, Pa. 124

IV. Map of north workings in Hillman bed, South Wilkes-Barre mine, Pa. 126

V. Map of Baltimore, Five-foot, and Hillman workings, in Dorrance mine, Pa 128

VI. Map of workings in Pittston bed, No. 14 mine, Pa 138

VII. Map of part of southern Illinois coal field, showing some features of the occurrence of methane 178

FIGURE 1. Section showing conditions at place where outburst occurred in the Jarrow mine, England 25

2. Diagram showing rate of escape of methane from coal under various conditions 40

3. Diagram showing rate of escape and volume of methane from 8 samples of American coals 43

Page.
FIGURE 4. Gas pressure in holes of various depths in English mines........... 63
5. Plan and sections showing location of holes for gas-pressure tests at Belle-Vue mine, Belgium.................................. 65
6. Diagram of pressures in test holes at Belle-Vue mine.............. 66
7. Diagram of pressures in test holes in coal at Belle-Vue mine, Belgium, while the rock tunnel was being continued to the coal.... 66
8. Diagram showing position of test holes at Beaulieusart mine and points at which gas outbursts occurred in driving the rise....... 67
9. Diagram of pressures in test borings at Beaulieusart mine.......... 68
10. Curves showing variations in volume of methane and carbon dioxide in relation to variations in atmospheric pressure, Gemeinschaft and Ath-Gouley mines.................................... 85
11. Curves showing variations in percentage of methane and barometric pressure in the Gabrielle mine, Karwin, Austria................... 87
12. Curves showing relation between length of flame of a blower and variations in atmospheric pressure, November, 1885, to January, 1886, at Hanover mine, Westphalia................................ 89
13. Curves showing variations in volumes of methane and carbon dioxide in return air at Tiefbau shaft, Austria, showing relation of variations in atmospheric pressure and also of amount of coal mined... 91
14. Curves showing variations in percentage of methane and barometric pressure in Du Souich workings, Liévin, France, during April, 1907.. 93
15. Ideal section through coal workings showing area in which flow of gas is affected by removal of coal............................ 95
16. Curves showing variations in atmospheric pressure, percentage of methane in return air, and earth tremors at the Herin mine, Anzin, France, August to December, 1886..................... 100
17. Curves showing variations in atmospheric pressure, percentage of methane in return air, and earth tremors at Herin mine, Anzin, France, December 6 to 10, 1886............................. 101
18. Columnar sections showing stratigraphic position of coal beds in northern anthracite basin....................................... 106
19. Columnar section of coal measures at Lance mine, Plymouth, Pa... 108
20. Generalized cross section of Lance mine, Plymouth, Pa............ 109
21. Sketch map of worked area in Red Ash bed, Lance mine......... 111
22. Sketch map of worked area in Ross bed, Lance mine............. 112
23. Sketch map of worked area in Bennett bed, Lance mine........... 113
24. Sketch map of worked area in Cooper bed, Lance mine........... 114
25. Sketch map of worked area in Five-foot bed, Lance mine......... 115
26. Sketch map of worked area in Hillman bed, Lance mine.......... 117
27. Sketch map showing thickness of valley filling, Lance mine...... 121
28. Map of Red Ash workings in Dorrance mine, Wilkes-Barre, Pa.... 130
29. Map of Red Ash workings in Hoyt mine, showing course of air currents sampled in November, 1910............................ 135
30. Map of workings in Dunmore bed, Sloan mine.................. 140
31. Section through Auchincloss mine near Nanticoke, Pa., showing the great overturn in the lower beds.......................... 158
32. Tube inserted in coal to ascertain pressure and flow of gas........ 214
33. Relation between depth of mines and amount of methane per ton of coal mined in southern Illinois.............................. 223

OCCURRENCE OF EXPLOSIVE GASES IN COAL MINES.

By N. H. Darton.

INTRODUCTION.

This report presents the results of an investigation begun by the Government in the summer of 1907, the investigation being started under the immediate supervision of Dr. J. A. Holmes and continued under him as director after it was transferred to the Bureau of Mines in 1910, the field studies being completed in the spring of 1912. The purpose of the investigation was to obtain information on the origin of the inflammable gases in coal and the conditions under which they occur. It was especially intended to ascertain whether there was any relation between the occurrence of gas and the structural or other geologic features of the coal beds. To this end many months were spent in mines and much time was devoted to the examination of mine maps, bore-hole records, and other data made available by the kindness of various coal companies. Two fields of work were selected—one in the northern anthracite basin of Pennsylvania, where the beds are considerably flexed, and the other in the southern part of the bituminous coal field of Illinois, where the beds lie nearly horizontal.

In order to take advantage of results of previous investigations of the same general subject, an extended examination was made of reports of various investigators in Europe and America. A digest of the information obtained from these publications is included in the first part of this report, which constitutes an introduction to the discussion of the conditions governing the occurrence of inflammable gas in coal beds.

THE GASES IN COAL AND THE CONDITIONS CONTROLLING THEIR ESCAPE.

GENERAL CONSIDERATIONS.

All coal contains in its pores and crevices some inflammable gas. This gas is given off when the coal is in the ground, during mining, and for a long time after the coal has been taken from the mine. Peat and marsh muck have the same property; hence the name "marsh gas," which indicates a source in organic material in marshes, is given to methane, the principal inflammable gas in coal.

The amount of gas in coal, the relative proportions of its constituents, and the volume given off vary greatly. In some coals and in some areas the amount of inflammable gas evolved is so small that the mines are classed as "nongaseous." Probably, however, no coal is entirely free from inflammable gas, and if only a small amount now comes from any given coal most of the original content has been lost previously. On the other hand, some coals give off several times their volume of gas that contains a large proportion of methane. In the anthracite region of Pennsylvania there are many mines, from each of which every minute more than 2,000 cubic feet of methane, or nearly 3,000,000 cubic feet every 24 hours, escapes into the air at the mouth of the upcast.

At ordinary temperatures most coals yield an equal volume of gas, or 20 cubic feet to the ton; some yield five times as much, and samples of a few coals have yielded gas at the rate of 150 cubic feet per ton. A volume greater than 100 cubic feet per ton of coal (20 to 25 cubic feet) is, however, relatively rare. The proportion of methane in the gases given off also varies greatly, but from most coals is in excess of 75 per cent.

Inflammable gas is liberated from coal in nearly all mines, but in most shallow mines the volume given off is small, and even in some deep mines of certain districts only moderate ventilation is necessary to keep methane from accumulating sufficiently to be detected with a safety lamp. Unfortunately, however, gas is given off unevenly from place to place in a bed, and in many mines large volumes occur unexpectedly. Wherever inflammable gas is allowed to accumulate an explosion may happen. Formerly all coal-mine explosions were attributed to ignited gas, but now it is known that in large explosions coal dust is the main explosive agent. Most gas explosions are small, but they are frequent in gaseous mines, and many of them cause fatal burns. Most afterdamp, or air vitiated by the products of an explosion, contains dangerous constituents, the most poisonous of which is carbon monoxide.

CHARACTER OF MINE GASES.

Only a brief outline of the character of the principal gases in mines is given, as the subject is treated in many books.[a] Methane (CH_4) is the most important of the mine gases on account of the fact that mixtures of methane and air in certain proportions are explosive. Carbon dioxide (CO_2) is also a common constituent of mine gases even when methane is absent, but only in exceptional instances is the proportion sufficient to be of practical importance. Carbon monoxide (CO) rarely occurs in mines except as a product of incomplete combustion. Oxygen and nitrogen, in the form of air and in proportions other than those in which they occur in air, are contained in gases extracted from coal, and in coal-mining operations large volumes of these gases, as air, are made to pass through the workings to dilute and remove the mine gases. In places mine air carries small amounts of various hydrocarbon compounds besides methane, and hydrogen and hydrogen sulphide occur locally in certain mines.

METHANE.

As expressed by its chemical symbol, CH_4, methane is a compound of 1 atom of carbon and 4 atoms of hydrogen. It is a colorless, odorless gas, and at ordinary temperatures is chemically inert. On ignition, it unites with oxygen to form carbon dioxide and water vapor. In places it is given off nearly pure by the coal but in most mines it is mixed with more or less carbon dioxide, nitrogen, and oxygen. Its specific gravity in comparison with air is 0.55314; that is, it is slightly more than half as heavy. Seemingly it is not poisonous when mixed with sufficient oxygen to support respiration. Some poisonous effects that have been ascribed to the presence of methane in large quantities are undoubtedly those of suffocation, possibly being increased in certain instances by some poisonous gas. Many miners work all day in air containing 1 to 4 per cent of methane without evidence of injurious effects. An experiment by Haldane[b] is on record in which he breathed a mixture of 20 per cent methane and 80 per cent oxygen for 5 minutes without any unfavorable results and a mouse kept in the mixture for 40 minutes was not affected.

CARBON DIOXIDE.

Carbon dioxide (CO_2) is of general occurrence in coal, and is a common constituent of mine air, but the proportion in most mine air is less than 1 per cent. It is without odor or color and is more than half again as heavy as air, its specific gravity being 1.529. It is neither explosive nor poisonous but is incapable of supporting life or combustion. In places it accumulates in pits and dug wells. A person descending into such a pit may be suffocated if the proportion of oxygen is much less than 10 per cent.

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[a] Much information is given by Beard, J. T., Mine gases and explosions, 1908, 402 pp. For a résumé of data relating to gases and methods of analysis see Burrell, G. A., and Siebert, F. M., The inflammable gases in mine air: Tech. Paper 39, Bureau of Mines, 1913, 24 pp.; the sampling and examination of mine gases and natural gas; Bull. 48, Bureau of Mines, 1913, 50 pp.

[b] Haldane, J. S., Investigation of the occurrence, properties, and composition of black damp: Trans. Fed. Inst. Min. Eng., vol. 8, 1894–95, p. 549.

CARBON MONOXIDE.

Carbon monoxide (CO) is rarely an ingredient of gases issuing from the coal and when it exists in mine air is generally a product of incomplete combustion, whether that of an explosive, of coal or wood in a mine fire, or of explosions of coal dust. It is the principal toxic agent in afterdamp. It is a colorless, odorless gas slightly lighter than air, strongly explosive and extremely poisonous. Air containing a very small proportion of carbon monoxide will cause death especially if the proportion of oxygen is diminished. The amount that can be endured by a person depends mainly on his vitality and the length of time he breathes the gas, but no one can survive more than a few moments in air containing 0.5 per cent. The effect is cumulative and half this proportion would be fatal if breathed for a long time. Removal from the poisoned atmosphere and vigorous long-continued artificial respiration with plenty of air, or better, oxygen, may save a person who has succumbed. The chances of recovery are, however, much less than in suffocation by carbon dioxide or other inert gas.

NITROGEN AND OXYGEN.

Nitrogen is almost invariably a constituent of the gas emanating from coal, in some mines constituting 90 per cent of the gas. In most mines it is mixed with oxygen in various proportions. Air consists of a mixture of approximately 79 per cent nitrogen, 21 per cent oxygen, and 0.03 per cent carbon dioxide, but air in mines loses much of its oxygen by absorption by coal and by various oxidation processes. Air containing less than 7 per cent of oxygen will not support human life.

FIRE DAMP.

The term fire damp is applied to mixtures of methane and atmospheric air; generally to those mixtures that are inflammable or explosive or nearly so. As stated above, pure methane is not explosive because a large volume of oxygen is required for its combustion; neither is a mixture of air and a small percentage of methane explosive. Generally fire damp contains 10 to 30 per cent of methane, for the gas as it emerges from the coal is mixed with more or less air, but in places where the air has been displaced, the proportion of methane may rise much higher; 99.5 per cent was found at a pit in Westphalia in 1894 and 1895. The gas extracted from fresh samples of coal, "blower gas," and gas accumulations in cavities in the roof where little or no fresh air has had access are much richer in methane than is ordinary fire damp.

The ignition and explosion of fire damp are subjects treated in various books on mine ventilation and mine gases, and their discussion is not within the scope of the present investigation. However, a few general properties may well be restated here. It is generally agreed that a mixture of methane and air containing 9½ per cent methane causes the most violent explosion, and Burrell and Siebert [a] have found that mixtures containing less than 5.5 per cent or more than 12.8 per cent will not explode, the explosive power being greatest when the proportion of methane is between 8 and 12 per cent. The limit of inflammability is reached at about 30 per cent, the mixture burning quietly between this proportion and explosibility.

The limits of explosibility are materially affected by the presence of carbon dioxide [b] and other gases and by coal dust in suspension. The factor of air movement is also of moment. Hydrocarbon gases other than methane increase the explosibility of the mixture, as does also carbon monoxide, but these gases are of infrequent occurrence. Carbon dioxide and nitrogen greatly reduce the explosive range, the most explosive mixture becoming inert when diluted with about 15 per cent of either or both of these gases. A mixture of 1 volume of methane and 9.55 volumes of dry air ignites at 1,200° F., the calculated temperature of the combustion being 3,900° F.[c] The pressure developed by such a mixture when it is ignited in a closed space is 102½ pounds to the square inch, which explains why a gas explosion in a mine does so much damage. Probably in a confined space in a mine all the methane does not burn completely in the explosion, for the proportion of oxygen may vary and some of the gas is forced in advance of the explosion wave (and hence is not burned) by the violence of the initial explosion. The presence of coal dust, especially the inflammable dust of bituminous coal,[d] is also most important.

NATURE OF GASES IN COAL BEDS.

Many analyses have been made of the gases given off in the mine by coal and by "blowers" and "feeders." Methane is the predominant gas in most places, but its proportion is exceedingly variable, in general ranging from 75 to 99 per cent of the gases as given off. Carbon dioxide is an almost invariable constituent, and the proportion, although usually less than 2 per cent, may be much greater in certain places. Nitrogen and oxygen are also present. Carbon monoxide, hydrogen sulphide, and various hydrocarbon compounds are of much less frequent occurrence.

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[a] Burrell, G. A., and Siebert, F. M., The inflammable gases in mine air: Tech. Paper 39, Bureau of Mines, 1913, 24 pp.

[b] Clement, J. K., The influence of inert gases on inflammable gaseous mixtures: Tech. Paper 43, Bureau of Mines, 1913, 24 pp.

[c] Mallard and Le Chatelier, Recherches expérimentales et théoriques sur la combustion des mélanges gazeux explosifs: Annales des mines, vol. 4, 1883, pp. 274–378.

[d] Rice, G. S., The explosibility of coal dust: Bull. 20, Bureau of Mines, 1912, 204 pp., 14 pls.; Coal-dust explosions, Miner's Circular 3, Bureau of Mines, 1911, 22 pp.; Frazer, J. C. W., Hoffman, E. J., and Scholl, L. A., jr., A laboratory study of the inflammability of coal dust: Bull. 50, Bureau of Mines, 1913, 58 pp.

COMPOSITION OF BLOWER GAS.

Chamberlin[a] compared the composition of gas extracted from coal samples in vacuum with gas from "feeders" in mines and bore holes and found that although the feeder gas bore a close resemblance to the gas extracted from lumps of coal and from finely crushed coal during the first few weeks under reduced pressure, it was, however, quite different from gas extracted from finely crushed coal that had lost most of its free gas by exposure to air for a few months. The samples he examined were from the Monongah mine, West Virginia.

The following results of analyses of inflammable gas found in different coal beds in the North of England were made by de la Beche and Playfair in 1846.[b]

Results of analyses of inflammable gas from British mines.

Source of sample.	Composition.				
	Methane.	Nitrogen.	Oxygen.	Carbon dioxide.	Hydrogen.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Wallsend colliery, pipe above ground	92.8	6.9	0.6	0.3	....
Wallsend colliery, Bensham bed	77.5	21.1	....	1.3	....
Jarrow colliery, Bensham bed	83.1	14.2	.6	2.1	....
Hebburn colliery, Bensham bed	86.5	11.9	....	1.6	....
Jarrow colliery, five quarter bed	93.4	4.9	....	1.7	....
Jarrow colliery, low main bed	79.7	12.3	3.0	2.0	3.0
Hebburn colliery, 24 feet below Bensham bed	92.7	6.4	....	.9	....
Gateshead colliery, Oakwell gate	98.2	1.3	....	.5	....

Le Chatelier from an extensive experience in mines in France and Belgium gives 78 to 99 per cent as the usual proportion of methane in gas from coal and less than 1 per cent as the usual proportion of carbon dioxide.

GAS FROM ENGLISH BLOWERS.

A sample of gas taken in 1893 from a blower at the Hebburn colliery, on the Tyne, England, had the following composition:

Composition of gas from blower, Hebburn colliery.

	Per cent.
Methane	78.8
Nitrogen	18.6
Oxygen	1.7
Carbon dioxide	.9

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[a] Chamberlin, R. T., Notes on explosive mine gases and dusts, with special reference to explosions in the Monongah, Darr, and Naomi coal mines: Bull. 26, Bureau of Mines, 1911, p. 32; reprint of U. S. Geol. Survey Bull. 383.

[b] Playfair, Lyon. On the gases evolved during the formation of coal: Mem. Geol. Survey Great Britain, vol. 2, 1846, pp. 460-479. Trans. North of Eng. Inst. Min. and Mech. Eng., vol. 12, 1862, pp. 190-201.

The gas continued to blow for a long time, and analyses made at intervals showed but little variation in the percentage of methane.

Gas from a blower in the Dunraven mine, South Wales, is reported to contain 96.7 per cent methane, 2.8 per cent nitrogen, and 0.47 per cent carbon dioxide.

GAS FROM AUSTRIAN MINES.

The Austrian Fire Damp Commission [a] analyzed many samples of gas from coal mines in Austria; the following is an average of samples from five different sources:

Average composition of blower gas from Austrian coal mines.

	Per cent.
Methane	91.0
Carbon dioxide	.8
Nitrogen	7.1
Oxygen	.5
	99.4

A sample from a blower in lignite at Trifail contained 1.4 per cent hydrogen and 7.7 per cent carbon dioxide.

In a mine at Karwin, Austria, a sample of gas from one blower contained 99.10 per cent methane.

Inflammable gas from a dip drift in Glückhilf colliery, Waldenburg, was analyzed by Poleck [b] for the Austrian commission, with results as follows:

Results of analysis of gas from drift in Glückhilf colliery, Waldenburg.

	Per cent.
Methane	32.65
Ethane (C_2H_6)	3.99
Carbon dioxide	41.49
Carbon monoxide	1.87
Oxygen and nitrogen	20.00
	100.00

This is, however, a most unusual combination and the carbon monoxide may be the result of some special reaction.

GAS FROM PRUSSIAN MINES.

In 1882 to 1884 Schöndorff [c] made a series of analyses of gases from coal for the Prussian Fire Damp Commission, with the results following.

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[a] Atkinson, W. N., Digest of report of Austrian Fire Damp Commission: Trans. Fed. Inst. Min. Eng., vol. 3, 1891-92, p. 531.

[b] Redmayne, R. A. S., Modern practice in coal mining, vol. 4, 1911, p. 35.

[c] Report of the Prussian Fire Damp Commission (translation), Trans. Fed. Inst. Min. Eng., vol. 3, 1892, pp. 1134-1135.

Results of analyses of samples of inflammable gas from Prussian mines.

Source of sample.	Composition.				
	Methane.	Ethane.	Hydrogen.	Carbon dioxide.	Oxygen and nitrogen.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Blower in Bonifacius mine, Essen	90.94		1.40	0.30	7.36
From water in sump, Kreuzgräben mine, Saarbrücken	[a] 57.41		5.68	1.54	35.37
Blower in No. 1 shaft, Consolidation mine, Schalke	89.88		5.84	.67	3.61
Blower in Shamrock mine, Herne	83.97		2.15	.77	13.11
In rise, in Lothringen mine, Castrop	[a] 27.95		1.35	.45	70.25
In roof of Maria mine, Höngen	[a] 14.25		.90	.10	84.75
Drift in Zollern mine, Dortmund	[a] 7.00		.27	.41	92.32
In roof of Tremonia mine, Dortmund	[a] 9.58		.36	.98	89.08
Drift near blower in Neu Iserlohn mine, Langendreer	[a] 4.75		.09	.13	95.03
Blower in König mine, Saarbrück	84.89	1.62		.65	12.84
Blower in Schaumburg mine, Obernkirchen	60.46	37.62		2.56	
Blower in mine, Waldenburg, Lower Silesia	57.33	.32		.12	42.23

[a] Probably more or less diluted by air.

The large proportion of ethane in the blower in the Schaumburg mine at Obernkirchen is a notable feature. The return air from certain levels in this mine was found to carry 0.22, 0.19, 0.35, and 0.10 per cent of ethane, with 0.96, 1.20, 1.02, and 1.11 per cent of methane, and the air had a strong odor of petroleum.

GAS FROM BORE HOLES IN ANTHRACITE REGION, PA.

Some of the holes bored, through the valley filling, into the coal measures near Wilkes-Barre and elsewhere in Luzerne County, Pa., have tapped gas in considerable volume. One notable example is found a few rods southeast of Luzerne, where a pipe in a 98-foot hole sunk 11 feet into coaly shale has been giving off gas for years.

A sample of this gas was collected and analyzed by Chamberlin [a] with the following results:

Results of analysis of gas from hole near Luzerne, Pa.

	Per cent.
Methane	91.31
Olefins	.49
Carbon dioxide	1.59
Carbon monoxide	.04
Hydrogen	.82
Air	1.10
Nitrogen (excess)	4.65

A sample of gas from a bore hole in coal at the foot of No. 11 slope in the Dorrance mine was collected on September 4, 1908, and analyzed by Chamberlin with the following results:

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[a] Chamberlin, R. T., Notes on explosive mine gases and dusts, with special reference to explosions in the Monongah, Darr, and Naomi coal mines: Bull. 26, Bureau of Mines, 1911, p. 31.; reprint of U. S. Geol. Survey Bull. 383.

Results of analysis of gas from bore hole in Dorrance mine.

	Per cent.
Methane	90.65
Olefins	.09
Carbon dioxide	.05
Carbon monoxide	.00
Hydrogen	.77
Air	2.73
Nitrogen (excess)	5.71

GAS FROM FRENCH MINES.

Schloesing [a] has given a series of analyses of samples of strong fire damp from representative French mines as follows:

Composition of samples of fire damp from representative French mines.

Mine.	Methane and other hydrocarbons.	Carbon dioxide.	Oxygen.	Nitrogen.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Anzin (Herin)	96.9	0.4	0.5	2.2
Anzin, Renard at 476 m	96.4	.0	.1	3.5
Anzin, Renard at 546 m	90.2	.3	.0	9.5
Le Grand-Combe, Oules shaft	81.8	1.1	9.5	16.6
Le Grand-Combe, Ravin mine	86.8	2.6	.4	10.2
Le Grand-Combe, Forêt mine	88.8	4.1	.0	7.1
Le Grand-Combe, Pontil shaft	88.5	2.7	.1	8.7
Le Grand-Combe, Trets dicht	81.1	3.3	.8	14.8
Aciériers de France	91.2	1.1	.3	7.4
Campagnac	92.5	.7	.0	6.8
Saint Étienne	94.6	.4	.1	4.9
Plat-de-Gier	78.6	1.0	.2	20.2
Roche la Moliere et Firminy	89.9	.9	.0	9.2
Rouchamp, Chanois shaft	92.7	.7	.0	6.6
Rouchamp, Chanois shaft (duplicate)	90.6	1.2	.1	8.1
Blanzy	55.6	3.7	.9	39.8

The nitrogen is believed to have been derived from outside air from which part or all of the oxygen had been absorbed by the coal, the proportion of argon to nitrogen being nearly the same as in air. The oxygen may also have been derived from outside sources. The methane in some of the samples, notably the last three, had associated with it ethane and possibly other hydrocarbons.

CONDITIONS UNDER WHICH GAS IS GIVEN OFF BY COAL.

Gas escapes from coal mostly by percolating through the minute spaces or pores between the coal grains and also in part through fissures most of which are minute. The pressure of the gas in the coal varies, and the permeability of the solid coal is slight and also variable, two factors that greatly affect the volume of gas given off.

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[a] Schloesing, T., Sur la composition du grisou: Compt. Rend., vol. 122, 1896, pp. 398–400; Abstract, Trans. Fed. Inst. Min. Eng., vol. 11, 1896, p. 611.

Where coal is shattered or pulverized by pressure and movement gas is freed in large volume as soon as the inclosing solid material is penetrated. Such gas emissions are known as outbursts. Gas accumulates in fissures rapidly if the fissuring is open and so far-reaching as to drain a large surface of coal. Very often, in mining gaseous coal, the gas issues from the fresh working face through many small fissures with a hissing or whispering sound, but some of the outflows are noisy, especially if the gas bubbles through water. Such larger flows of gas are called "blowers" or "feeders." Movements of roof or floor in coal mines and shattering of coal in ribs or pillars increase the general emission of gas. Some of the special conditions under which gas is given off by "blowers," outbursts, and squeezes are described in the following paragraphs.

OCCURRENCE OF "BLOWERS" OR "FEEDERS."

As previously stated, the term "blower" or "feeder" is used by coal miners to denote a flow of gas from a crevice. Usually the flow is from an orifice and the emission is noisy. More blowers occur in or near the roof or floor than in the solid coal, and some are in strata containing no coal. Many blowers are of great volume and of long duration, but most of the stronger ones are short lived and nearly all of them cease in time. A blower at Wellesmeiler, Saarbrücken, has been blowing for more than 50 years. The volume of gas given off by different blowers differs. One persistent blower in the Pelham mine in England in 1847 discharged a volume estimated at 47,000 cubic feet a minute, and one in a mine on the Tyne in England was reported as giving off 6,000 to 7,000 cubic feet per minute. A blower in the Wallsend Colliery, England, is reported by Abel[a] as giving off 120 cubic feet of gas a minute. The pressure of some blowers is as high as 50 pounds per square inch.

Blowers or similar noticeable gas emissions are not always an evidence of unusually gaseous coal, for blowers are found in mines where no great volume of methane is emitted by the coal, while, on the other hand, some gaseous mines have no large blowers. In a few mines in France, Belgium, and Germany blowers of carbon dioxide have been found.

Blowers undoubtedly have their origin in crevices in which gas accumulates or in fissures that lead from reservoirs in which gas has accumulated, such as porous sandstone, bodies of crushed coal, or a network of fissures.

A strong blower in the Garwood mine, England, is described by Smethurst.[b] It began in a shaft at a point more than 300 feet above the coal bed and had to be piped off as sinking progressed. It burned from the pipes for more than nine years, and at night the light could be seen for 10 miles.

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[a] Abel, Frederick, Accidents in mines: Proc. Inst. Civil Eng., vol. 90, 1886–87, pp. 160–200; vol. 91, 1887–88, pp. 36–190.

[b] Smethurst, W., Final report of Her Majesty's commissioners appointed to inquire into accidents in mines, 1886, p. 146.

OCCURRENCE OF GAS OUTBURSTS.

CAUSES.

Sudden outbursts of methane in mines indicate somewhat the conditions under which the gas occurs in the coal. These outbursts appear to be due to one of two causes, or a combination of them. One cause of outbursts is a run of coal, which may be produced either by gas or roof pressure, or both, or by mining into a body of shattered coal. Such a run exposes a large area of fresh coal surface, for usually, if the coal is not already much broken, it is greatly shattered by the movement, and thus a large volume of gas is rapidly liberated. The other cause is the opening of a fissure filled with gas under pressure, resulting in a sudden outburst of the gas. The ordinary gas outburst occurs when the pressure of gas exceeds the resistance of the coal, and this condition generally is found when workings in hard coal approach a body of softer or more porous coal containing a large volume of gas under high pressure.

INSTANCES OF SERIOUS OUTBURSTS.

THREE PENNSYLVANIA MINES.

Some very heavy gas outbursts are on record. An outburst at the Otto colliery, 6 miles west of Pottsville, Pa., liberated a body of gas estimated by the mine inspector, Samuel Gray, at 50,000 to 200,000 cubic feet.[a] It seemingly came from a great run on a 35° dip in the Mammoth bed and filled an air way for 225 feet. It was carried out by the ventilation without ignition except in one small area where some of it exploded, killing one man and burning several.

A notable outburst in the Knickerbocker mine near Mahonoy City, Pa., in August, 1908, dislodged about 150 cars of coal and gave off a great volume of gas, which suffocated several men. It occurred in a stope of rather steeply dipping beds near the crest of an anticline; the space from which the coal ran was about 6 by 8 feet in cross section and 66 feet long. An outburst in one of the mines near Connellsville, Pa., filled the workings with such a great volume of gas that 100,000 cubic feet of fresh air a minute for three days was required to reduce the proportion of gas in the mine air to a safe limit.

Probably some of the great coal-dust explosions in mines have been started by ignition of a gas outburst. These outbursts occur when the mining has progressed to the vicinity of the gas reservoir, and neither their occurrence nor their ignition can be connected with atmospheric or seismic influences.

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[a] Gray, Samuel, Explosion at Otto colliery, Pa.: Col. Guard., vol. 8, Nov. 1887, p. 87.

TWO BELGIAN MINES.

At the Agrappe colliery in Belgium, in 1879, an outburst occurred at a depth of 2,000 feet. About 85,000 cubic feet of gas was released so quickly that it reversed the air current and came to the pit mouth, carrying with it a large quantity of fine coal. One hundred and twenty-one men were killed and several others were injured. In the outburst of gas at Bessèges in Belgium, in 1890, 131 men were killed. It is stated that in this outburst 28,000 cubic feet of gas issued rapidly and the overflow continued until in 12 hours 180,000 cubic feet of gas had escaped. From 1850 to 1908 there were 357 serious outbursts in Belgian mines, 32 per cent of them being fatal, and causing the death of 447 men.[a]

MORRISSEY, B. C.

An outburst at Morrissey,[b] B. C., in 1904, emitted a volume of gas estimated at 5,000,000 cubic feet, and the great mass of fine coal thrown out, amounting to about 3,500 tons, extended 450 feet from the face. Fourteen men were suffocated, but all the lights went out suddenly and there was no explosion.

ABERCARNE MINE, WALES.

A great outburst[c] in the Black vein coal at Abercarne mine, south Wales, occurred in a gangway driving through compact coal, when it approached a zone of softer coal. The face blew out and a volume of more than 1,000,000 cubic feet of gas was estimated to have been given off in a short time.

CRUSHED COAL A CAUSE OF GAS OUTBURSTS.

Certain gas outbursts in mines have been found to be closely related to zones in which there has been extensive crushing of the coal, caused by earth movements, especially lateral thrust resulting in folds, buckles, and small faults. In such zones the coal is traversed by numerous crevices which serve as a reservoir for gas given off by the large area of surface exposed by the crushed coal. In an Australian mine the outbursts occurred near such cracks or zones of compression, where the coal was found to be extensively shattered. However, most gas accumulations resulting from such conditions, are found only in deep workings, for, if the beds are near the surface, the gas escapes through the broken strata. The outbursts in the mine at Bessèges in France have been described in detail by Ichon and

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[a] Described by Arnould, G., Étude sur les dégagements instantanés de grisou dans les mines de houille du bassin Belge: Ann. trav. pub. Belgique, vol. 37, 1880, pp. 1–108.

[b] Ashworth, James, Outburst of gas and coal at the Morrissey collieries, B. C.: Trans. Inst. Min. Eng., vol. 29, 1904–1905, p. 56.

[c] Final report of Her Majesty's commissioners appointed to inquire into accidents in mines, 1886, p. 23.

Lombard.[a] These outbursts were numerous and some of them violent, but as most of them gave premonitory indications no fatalities resulted. In one of the outbursts 50 tons of coal was thrown out, and it is estimated that 28,000 cubic feet of methane was given off in the first two and one-half minutes and 175,200 cubic feet in 12 hours. Most of the outbursts were in soft coals, and in coal either normally gaseous or showing less gas than usual, in some instances with harder coal behind. Several occurred in mines where there were small breaks in the coal measures, but most of them were in solid coal. Test holes were not found efficacious either for warning or for decreasing pressure, and they gave a false sense of security.

DISCUSSION OF OUTBURSTS IN BELGIAN COAL FIELDS.

Extended descriptions of the gas outbursts in the Belgian coal field are given by Arnould,[b] Dufrane,[c] Roberti-Lintermans,[d] and Stassart and Lemaire.[e]

According to Roberti-Lintermans these sudden outbursts occur in mines along the southern boundary of the field and in only a few beds. Most of the outbursts were at depths of 1,200 to 2,000 feet, but a few were in workings at depths of 2,000 to 3,500 feet. The general dip of the measures has no relation to the accumulations of gas, as the outbursts were as numerous in horizontal as in inclined parts of the same bed. The gas accumulations are, however, closely connected with local disturbances of the strata, such as sudden upturns or faults, folds, or thinnings out of the coal bed, for of 131 outbursts studied only 22 occurred in places where the beds were undisturbed. Most of the outbursts were sudden, and only a few gave premonitory signs. The majority occurred in places where no appreciable volumes of gas had previously been noticed.

OUTBURSTS IN AGRAPPE, PRODUITS, AND MARCINELLE-NORD MINES.

The great outbursts in the Agrappe mine were in horizontal measures where no large quantities of gas had been observed before. An outburst in that mine in October, 1880, threw 1,650 bushels of coal and coal dust into the passages. In June, 1886, in the same vicinity after four test holes had been bored 16 feet without showing signs of extra gas, suddenly 13,750 bushels of coal was thrown out and gas filled the stope for 109 yards. In April, 1885, in a coal mine at Marcinelle-Nord, with several 23-foot bore holes in advance and no signs of extra gas, 3,437 bushels of dusty coal was thrown out and 18 men suffocated. All the gas and coal came from a face only 6½ by 6½ feet. At the Produits colliery, in April, 1891, in a crosscut that had just reached coal, four advance holes through the bed showed so little gas that shots were fired. The shots were followed by a great outburst in which the gas came to the downcast shafts. From one bed in this mine there were 23 small outbursts, at the rate of about two a month. In several instances the methane emanation at the place of outburst notably diminished or ceased for a while before the outburst.

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[a] Ichon and Lombard, Note sur les dégagements instantanés de grisou aux mines de Bessèges: Annales des mines, ser. 9, vol. 1, 1892, pp. 557–603.

[b] Arnould, M. G., Étude sur les dégagements instantanés de grisou dans les mines de houille du bassin Belge: Ann. trav. pub. Belgique, vol. 37, 1880, pp. 1–100.

[c] Dufrane, A., Les dégagements instantanés de grisou: Bull. Soc. l'indus. min., ser. 3, vol. 1, 1887, pp. 507–593.

[d] Roberti-Lintermans, Frederic, Les dégagements instantanés de grisou dans les mines de houille de Belgique: Ann. trav. pub. Belgique, vol. 52, 1896, pp. 76–244. Review by F. Delafond in Annales des mines, ser. 9, vol. 10, pp. 653–669: Translated in Colliery Guardian, vol. 74, July 9, 1897, pp. 61–62.

[e] Stassart, Simon, and Lemaire, E., Les dégagements instantanés de grisou dans les mines de houille de Belgique: Ann. des mines de Belgique, vol. 15, 1910, pp. 93–252, 665–786, 1216–1308, 1737–1810.

The outbursts of greatest intensity were in crosscuts; they became more frequent and serious as the depths increased, none of importance occurring above a depth of 1,000 feet. In most outbursts the gas is seemingly stored in bodies of permeable coal inclosed in more compact coal; barriers or dams of this character were noted in the Agrappe mine. The high pressure of gas in solid coal noted by various observers indicates that this inclosing material must be almost impervious in order to retain the gas which is under considerable pressure. When the outbursts take place the shattered coal quickly gives off most of its gas. That gas in solid coal can not be drained by bore holes is generally believed, for such holes do not break down enough coal to give outlet to any great volume of gas and, therefore, relieve the pressure only in their immediate vicinity. Gas is given off slowly from compact coal even when the pressure is high, but in approaching zones of shattered coal bore holes in advance of the face might drain some gas. This measure was tried in some of the French and Belgian mines and although in several instances the holes did not even indicate an approaching outburst, in others they delivered a large amount of gas. This question has been discussed by Roberti-Lintermans [a] and by Dufrane [b] in considerable detail. They discuss various methods for avoiding or obviating outbursts.

INVESTIGATIONS OF STASSART AND LEMAIRE.

The detailed investigations of outbursts in Belgian mines by Stassart and Lemaire [c] verified most of the conclusions of previous observers and also brought out various additional facts of interest. They found that the upper series of coals with the largest percentage of volatile combustible matter were the least gaseous and that beds that were very gaseous in one place were much less so in others and below a certain stage the occurrence of gas was without relation to depth. They found also that in some places outbursts were much more likely to occur under the overturned folds and along overthrust faults, especially in overthrust blocks, in all of which the coal was so shattered that gas was given off rapidly. In general, the more gaseous coal was in zones and masses irregularly distributed; this condition is believed to be due largely to areal variations in the amount of gas developed in the original vegetal deposits or kept in them by impervious cover.

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[a] Roberti-Lintermans, Frederic, op. cit., pp. 230–231.

[b] Dufrane, A., op. cit., p. 564.

[c] Stassart, Simon, and Lemaire, E., loc. cit.

OUTBURST DUE TO ROOF FALL OR MOVEMENT OF FACE.

Some outbursts are due to a roof fall, many of which are caused by the pressure of the gas; in others the falling rock may disclose a gas-filled crevice, or a large block of coal may be detached from the face leaving an opening from which gas flows in large volume either from crevices or from a mass of shattered coal behind. A good illustration of such a case is given in a description by Buddle [a] of an outburst in the Jarrow mine in August, 1830. The outburst came from the face of a drift that was 9 feet wide and 5 feet high. The whole block of coal was forced forward seemingly with great violence, leaving a jagged aperture 9 to 12 inches wide along the roof and down the left side. The block was 4 feet thick, and behind the block a space 7 feet wide extended to a fault with a drop of 3½ feet. This space was filled with disintegrated coal of a sooty appearance. No gas was found before or after the outburst. From this fact it would appear that an isolated reservoir of gas had accumulated in the coal shattered by the fault movement. It was not in communication with a blower, and the gas was quite exhausted by the single eruption. The conditions that existed at this place are shown in figure 1.

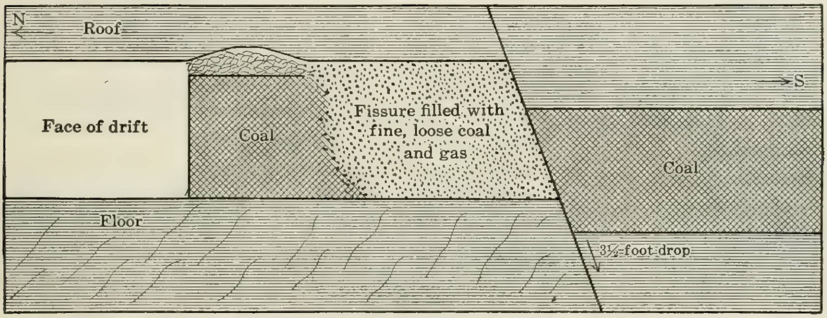

FIGURE 1.—Section showing conditions at place where outburst occurred in the Jarrow mine, England.

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[a] Buddle, John, Account of an explosion in Jarrow colliery, Aug. 3, 1830: Trans. Nat. Hist. Soc. of Northumberland, vol. 1, 1831, pp. 184-205; Compt. Rend., vol. 2, 1836, pp. 323-324.

GAS FROM SQUEEZES.

The subsidence of an undermined area in a coal mine, known as a squeeze, is attended by the emission of an increased amount of gas, the volume in some instances being large. The emission is caused partly by the crushing of coal in the pillars so that the gas that comes from them gradually under normal conditions is freed quickly. The roof is cracked to some extent and ventilation is usually cut off, at least along some of the main airways.

In the squeeze at the Stevens mine near Pittston, Pa., in July, 1904, a large volune of gas was liberated from workings in the Marcy and Red Ash beds. The air current of 120,000 cubic feet a minute brought so much gas from the squeeze that the return air would flame in a safety lamp set near the fan in the upcast a mile distant. This condition continued for four weeks while the operators were trying to arrest the squeeze.

A squeeze at the Warrior Run mine near Wilkes-Barre, Pa., in August, 1906, was in beds E, F, D, C, and Y, under an area of 40 acres. The affected area was in the north basin which extends from the anticline down to the bottom of the workings. In the crest of the anticline there was 350 feet of rock cover, but the volume of gas was so great that it came to the surface and at one place caused a serious explosion.

METHANE IN COAL.

ORIGIN.

Methane undoubtedly is a product of the decomposition or molecular rearrangement of organic matter during its transformation into coal, putrefactive bacilli being the cause of the change. It is reasonable to believe that the process may have lasted for some time, but all the evidence now available appears to indicate that it is no longer in progress in the coal. Possibly, however, the diminution of underground pressure in the coal deposits by erosion and mining may be a factor in the disassociation of some as yet unrecognized intermediate compounds with emanation of more or less additional methane.

It appears highly probable that different conditions of bacteriologic action in the original vegetable accumulations have had much to do with the cause of variations in the amount of methane in coal. The first and most important change in the transformation of organic matter into coal is putrefaction, sustained by certain bacilli; this process and others causing changes in the carbon compounds progress until the material reaches the stage of peat. Elaborate studies of these processes made by various observers, notably by Renault [a] in France, have aided greatly in determining the organic and chemical conditions involved in the change of vegetable matter to coal. Renault discovered abundant remains of many microorganisms in coal and coaly substances. He and others have found that the putrefaction in vegetable accumulations is caused and sustained by a large variety of organisms, depending somewhat on the nature of the materials which comprise many kinds of plants, on numerous local conditions of temperature, moisture, etc., and on the rate of accumulation. Thus their chemical products may vary considerably.[a] The precise chemical reactions are not well known, but in general there is elimination of oxygen and hydrogen with consequent evolution of more or less carbon dioxide and methane. In some stages there are developed by-products that arrest putrefaction, so that it proceeds irregularly in the mass and with varying proportions of resultant gases. The degree of decomposition at the time the coal deposit is buried may be an important factor, and the nature of the covering material, whether sand or clay, and its rate of deposition probably have great influence on the amount of gas retained. Doubtless these two features, the variations in kind and degree of putrefaction and the cover conditions imprisoning the gas in the coal, have most to do with variations in the amount of gas in the coal as now found. Naturally, they varied greatly from place to place and from time to time in basins where vegetable deposits were accumulating and being buried, so that the great variation in volume of methane now found in the coal was largely caused early in the history of the beds. Of course there has also been subsequent escape of gas through porous overlying strata, especially as uplift has brought up the coal measures and they have been more or less bared by erosion. As a result of erosion, the escape of gas has progressed without relation to the original content, and the result gives further complexity to the problem.

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[a] Renault, B., Sur quelques microorganismes des combustibles fossiles: Bull. Soc. l'indus. min., ser. 3, vol. 13, 1899, pp. 965-1161; vol. 14, 1900, pp. 5-159; Les bactériacées des bogheads: Compt. Rend., vol. 124, 1897, pt. 1, pp. 1315-1318.

RELATIONS TO CLASS OF COAL AND METAMORPHISM.

It does not seem possible to reconcile the methane conditions in coal with generally held theories ascribing the cause of the differences between varieties such as anthracite, bituminous coal, and lignite to fractional distillation after the coal had been buried in the coal measures. It is assumed in such theories that more or less of the volatile matter was baked out by underground heat or "metamorphism" and escaped through porous rocks or joints.[b] The baking of coal seen where igneous intrusions have occurred is cited as an illustration of the phenomenon. The nature of the resulting product is supposed to depend upon the stage to which the process advanced, graphite and anthracite being greatly baked, and most lignites having lost little of their original volatile components. Anthracite differs from bituminous coal and lignite in composition mainly in that it contains only about 2 per cent of oxygen instead of 15 to 20 per cent or more. In part of the anthracite basin of Pennsylvania it was found that the amount of methane is far greater than in most bituminous coal fields.

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[a] See White, David, and Thiessen, Reinhardt, The origin of coal: Bull. 38, Bureau of Mines, 1914, 390 pp.

[b] Campbell, M. R., Hypothesis to account for the transformation of vegetable matter into the different grades of coal: Econ. Geology, vol. 1, 1905, pp. 26–33; White, David, Some problems of the formation of coal: Econ. Geology, vol. 3, 1908, pp. 292–318.

As anthracite in America and Europe contains many volumes of highly volatile methane which must be believed to have been developed during the original formation of the coal, it is impossible to conceive of the distillation of the heavier hydrocarbons of the so-called "volatile matter" of the coal and the retention of the great volume of methane. It implies that vast volumes of "volatile matter" have escaped from coal through strata which are sufficiently impermeable to prevent the escape of methane under high pressure. As shown above, it is most improbable that the methane developed after the metamorphism. Renault, Bertrand, and others have held that although metamorphic agencies may have acted to some extent, the differences in coals are mainly due to difference in character of vegetable accumulations, conditions of deposition, and the nature and degree of biochemical processes that have operated. Doubtless dynamic conditions have caused molecular rearrangement of some of the original components of coal, perhaps with more or less additional methane as byproduct, but the extent and the chemistry of the process have not been elucidated.

CONDITION OF METHANE IN COAL.

The condition under which methane is included in the coal in such large volume is still an unsolved problem. It has been thought that the gas may be dissolved in the coal, as salt dissolves in water and gases intermix, or the gas may be, in part at least, in the form of CH compounds, subject to molecular rearrangement with evolution of methane. The most general opinion is, however, that the gas is inclosed in minute "pores" or crevices of various sizes and manifestly under high pressure, as indicated by the large volume found. It has been suggested that the methane in coal may be in liquid form, but with pressure of 735 pounds to the square inch the temperature of condensation of methane is −114° F.[a] The word "occluded," which has been applied in various senses, is misleading. Chamberlin[b] states that even if gases are dissolved in coal they are also held in the minute pores and cavities as well as in the larger crevices, where their presence usually is evident. Analyses of gases given off by samples of coal kept in bottles for a long time show that methane is not forming in the coal, at least under laboratory conditions, for the gas emanation diminishes steadily.

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[a] Burrell, G. A., and Seibert, F. M., Sampling and examination of mine gases and natural gas: Bull. 42, Bureau of Mines, 1913, p. 107.

[b] Chamberlin, R. T., Notes on explosive mine gases and dusts, with special reference to explosions in the Monongah, Darr, and Naomi coal mines: Bull. 26, Bureau of Mines, pp. 16-17; reprint of U. S. Geol. Survey Bull. 383.

As the volume of gas spontaneously liberated from coal at ordinary temperatures is usually considerably more than the volume of coal and vastly more than that of the interstices or pores in even the most porous coal, its physical condition in the coal is problematical.[a] When coal is mined and broken up, the gas escapes rapidly from the pores and crevices, but under ordinary conditions mined coal is in compact lumps and much time is required for the complete liberation of the gas, especially when the tension or gas pressure has diminished.

Chamberlin [b] found that during the crushing of the coal in vacuum only about one-quarter as much methane was obtained from the sample as was obtained after it had been bottled for six months in a vacuum. It would seem that crushing of the coal would so shatter all particles that most of the gas could escape at once, but clearly a large amount is held so tightly that much time is required for its liberation.

RELATION OF METHANE TO AGE OF COAL.

There is no relation whatever between the occurrence of methane and the age of the coal, for all coals from Carboniferous to late Tertiary as well as peat and other vegetal accumulations in marshes give off methane. In some districts the younger coals may be more gaseous than the older ones, or vice versa, the difference being due to local conditions.

RELATION OF METHANE TO DEPTH OF COAL.

In general there is more methane in deeply buried coal beds than in beds near the surface, but seemingly the principal factor influencing this condition is the tightness of the cover. There is no evidence that the original content of gas in coal is in any way related to depth, but on the other hand, the proportion varies from bed to bed and in different parts of the same bed without relation to the present position of the surface. Many deep workings are free from large quantities of gas, notably the Monceau-Bayemont, Sacré Madame, Marchienne, and Poirier mines in Belgium. In investigating mines in various parts of the United States the author found that it is not always the deepest bed, or the deepest-lying part of the same bed, that gives off the most methane. Stainier [a] is of the opinion that in wide basins of coal accumulation the chemical changes that produce methane have increased in activity toward the centers of the basins, but these centers are not always at the bottom of the present synclines or structural basins. Moreover, conditions in some of the earliest deposits may not have been such as to produce the most gas. Stainier found that some of the coal areas in Belgium and France are remnants of a wide basin in which the proportion of volatile matter increases toward the center. On the original edges the beds are anthracite, even graphitic, and are thinner. After studying these beds over a wide area, he found that they were much more gaseous toward the center of deposition. Where this part of the field is in the deepest part of the structural basin the more gaseous coal lies at a great depth; but in some districts, on the other hand, the original centers of deposition have been uplifted into anticlines and either lie near the surface on the crests of these uplifts or have been entirely removed by erosion.

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[a] This question has been discussed at considerable length by G. Arnould, Étude sur les dégagements instantanés de grisou dans les mines de houille du bassin Belge.; Ann. Trav. Pub. Belgique, vol. 37, 1880, pp. 1-108.

[b] Chamberlin, R. T., op. cit. p. 32.

RELATION OF METHANE TO STRUCTURAL FEATURES.

Those who have studied the methane problem are generally agreed that structural disturbances alone do not affect the proportion of gas in coal. There are, of course, certain obvious relations when other conditions are equal; the more profound synclines carry the coal so deep that the factor of depth with increased thickness of cover becomes important; workings on anticlines may serve as reservoirs for gas; and zones of crushing contain coal in such condition that it readily gives off a large volume of gas. Many faults serve as channels by which gas may enter workings from lower beds, and shattered measures along faults may carry larger volumes of gas. On the other hand in many places the faults are outlets to the surface which drain off the gas near the plane of movement. A fault may also bring a relatively impervious mass of rock against gaseous beds in such a way as to prevent the escape of gas. In many of the districts where the gas content or pressure is greatest in mines the beds show no signs of structural disturbances or crushing.

In some Prussian mines it was found that in anticlines from which the crests had been removed by erosion, much of the gas had escaped, whereas in the anticlines in which the coal did not reach the surface a large volume of gas remained. This was well shown at Wurm, where coal in the limbs of anticlines that outcrop was free from methane to the deepest workings, whereas in the closed anticlines there was so much gas that it had to be drained off by advance drifts before mining could progress.

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[a] Stainier, X., Des rapports entre la composition des charbons et leurs conditions de gisement: Ann. des mines de Belgique, vol. 5, 1900, pp. 397–466, 529–590.

In some places more gas is encountered in horizontal beds than in those that are inclined, because the upturned strata are more shattered and the gas drains off through the joints and crevices.

RELATION OF METHANE TO CHARACTER OF COVER.

As no rocks are impermeable to gas, a certain proportion of the original gas content in all coal has come to the surface and drained into the atmosphere, and this process is continually in operation in all coal areas. Time, the porosity and thickness of the overlying deposits, and the volume and pressure of the gas are the important factors in the rate and extent of the drainage. The total amount of gas emanation by this avenue, however, may be only a small proportion of all that is contained in the coal where the bed lies deep and where the cover is fine grained and compact. That tightness of cover is an important feature is shown by the fact that in the Westphalian coal basin 90 per cent of the gas explosions were in the area in which there is a covering of chalk marl which is almost impervious. In the Obernkirchen district the main bed is especially gaseous only where the roof of porous sandstone is covered by Wealden clay, and in those mines in Natal where there is a thick covering of diorite much gas remains in the coal. Doubtless beds containing water impede the escape of gas more than the dry beds, for moisture must greatly diminish the porosity of the strata.

DIFFUSION OF METHANE.

Where methane is given off gradually from the pores and crevices in coal, generally there is perfect diffusion of the gas in the mine air, especially if the ventilation is active. However, where the gas comes from crevices, especially those near the roof, the methane, being lighter than air, rises to the roof and if the air is still remains there in a somewhat pure state. Carbon dioxide, on the other hand, being much heavier than air, tends to accumulate in low places. Of course the tendency of either gas to separate by gravitation is of no import if there is brisk air current, for diffusion is rapid when the air is in motion. Experiments show that three or four hours is required for complete diffusion of a body of methane lying on still air in a mine and that after the gas has been absorbed by the air it can not separate again.[a]

The Prussian commission[b] made tests at Neunkirchen on the diffusion of methane. The gas was introduced into compartments by a top inlet and in volumes corresponding to 3, 4, and 5 per cent of the size of the compartment. The diffusion progressed slowly but was complete in about four hours; in three hours it approached completeness. The composition did not change afterwards.

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[a] Coquillion, S. S., Sur la diffusion du grisou dans les mines: Compt. Rend., vol. 87, 1878, p. 65.

[b] Pellé, M., Expériences sur la diffusion de grisou: Annales des mines, ser. 8, vol. 9, 1886, p. 610; Trans. Fed. Inst. Min. Eng., vol. 3, 1892, p. 1141.

GASES IN COAL SAMPLES.

The many determinations of the volume and nature of gases in coal samples afford important evidence as to the conditions under which gas is given off in mines and the volume of gas to be expected from coal in mining. Some of these tests have been made by heating the samples and others by collecting gas given off at ordinary temperatures in varying periods of time. The results have shown great diversity in the volume of gas and in its components, not only in coals of the same class but in samples from different places in the same bed. A few representative analyses are given in the following pages. Seemingly no consideration has hitherto been given to the relation between gas content and composition of the coal, a subject that is treated in another section.

GAS FROM SAMPLES OF ENGLISH COALS.

In the earlier determination of gases liberated from coal samples each sample was heated to 212° F., a condition that gives a result not comparable with the emanation of gas at ordinary temperatures in coal mines. The figures obtained by Thomas[a] in 1875 from samples of various kinds of English coal are given in the following table:

Gas from samples of English coal.

Kind of coal.[b]	Volume of gas freed per 100 grams.	Approximate relative volume.	Constituent.			
			CH_4	CO_2	Oxygen.	Nitrogen.
	c. c.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Bituminous	55.9	0.75	36.42	0.80	0.00	62.78
Do	61.2	.82	16.77	2.72	.40	80.11
Do	55.1	.74	5.44	1.05	63.76	29.75
Do	24.0	.32	22.16	6.09	2.68	69.07
Do	39.7	.53	9.43	2.25	31.98	56.34
Semibituminous, steam	73.6	.99	12.34	.64	72.51	14.51
Do	194.8	2.63	5.04	.33	87.30	7.33
Do	250.1	3.38	13.21	.49	81.64	4.66
Do	218.4	2.95	5.46	.44	84.22	9.88
Do	147.4	1.99	8.90	1.02	67.47	12.61
Do	375.4	5.07	9.25	.34	86.92	3.49
Do	149.3	2.02	11.35	.56	73.47	14.62
Anthracite	555.5	7.50	2.62	....	93.13	4.25
Do	600.6	8.11	4.72	....	84.18	1.10
Wigan cannel	42.13	.57	80.69	6.44	....	....
Do	35.06	.47	77.19	9.05	....	....
Scotch cannel	16.80	.23	....	53.94	....	....
Do	55.70	.75	....	84.55	....	....
Whitehill cannel shale	55.70	.75	....	68.75	....	....
Whitby jet	30.20	.40	(c)	10.93	....	....

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[a] Thomas, J. W., Gases inclosed in coals from the South Wales basin, and the gases evolved by blowers and borings into the coal itself: Jour. Chem. Soc., vol. 28, pt. 2, 1875, pp. 793–822.

[b] As given in article cited.

[c] 86.90 per cent C_4H_{10}.

In making these tests the coal in one large piece was placed in a vacuum pump; when the air had been exhausted the temperature was raised to 212° F. It was found that the rate of emanation of the gas depended on the hardness of the coal and the quantity of gas it contained.

Bedson and McConnell[a] investigated gases contained in coal and coal dust from English mines. Material from a working face in the Ryhope mine gave particularly interesting results. Several clean fragments were heated in a vacuum to 212° F. for 119 hours and the product was tested at intervals. The samples yielded in the end an average of 10 to 11 volumes of gas, of which in the larger amount 1.75 volumes or 16 per cent was methane. The average composition of the gas was as follows:

	Per cent.
Methane	16. 6
Carbon monoxide	0. 1
Carbon dioxide	0. 7
Oxygen	9. 4
Nitrogen	73. 0

Most of the gas was given off in the first 5 hours at 86° to 158° F., but the proportion of methane increased steadily after 5 hours at temperatures of 158° to 197° F., probably because more of the included air had been driven off earlier in the test. However, the proportion of nitrogen increased steadily after 24 hours to the end of the test. The same samples were then powdered and heated in a vacuum for 26 hours at 212° F., a process that liberated less than one-fifth as much additional gas as had been obtained in the first 24 hours in the lump test. This gas contained 17.9 per cent methane, nearly the proportion that was contained in the total volume in the lump test, and nearly three times as much as came off in the last 27 hours in the lump test, showing that the liberation of the methane was greatly furthered by pulverizing the coal. Some heavier hydrocarbons were also liberated from the powdered coal, showing that they are held more tightly. In continuing these investigations[b] it was found that different coals showed great diversity as to volume, rate of liberation, and proportions of gaseous constituents.

GAS FROM SAMPLES OF GERMAN COALS.

Many determinations have been made of gas content of German coals. The following series, by Broockmann,[c] are of interest as showing especially low oxygen content. The tests were made of coal fragments freed, as far as possible, from air by standing in vacuum for three days. The gases represented in the table were obtained by heating the coal samples to 212° F. for several days, great precaution being taken to avoid the infiltration of air.

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[a] Bedson, P. P., and McConnell, W., Notes on the gases inclosed in coal and coal dust: Trans. Fed. Inst. Min. Eng., vol. 3, 1891-92, pp. 307-310.

[b] Bedson, P. P., and McConnell, W., A contribution to our knowledge of coal dust: Trans. Fed. Inst. Min. Eng., vol. 7, 1894, pp. 27-530; Trans. Inst. Min. Eng., vol. 24, 1902, pp. 27-40.

[c] Broockmann, K., Ueber die in Steinkohlen eingeschlossenen Gasse: Glückauf, vol. 35, 1899, pp. 269-274; Abstract in Trans. Inst. Min. Eng., vol. 24, 1902, pp. 18-26.

Gas from samples of foreign coals heated to 212° F.

Source of sample.	Approximate relative volume.	Composition of gases evolved.					
		Methane.	Carbon dioxide.	Oxygen.	Nitrogen.	Olefins.	Carbon monoxide.
Westphalia.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Smithy coal, President pit	1.1	96	2	....	2	....	....
Lean coal, Gabe Gottes bed	.6	75	22	....	3	....	....
Hibernia, coking coal, No. 13 bed	1.2	94	6	....	....	....	....
Rhein-Elbe, gas coal, No. 12 bed	.1	12	21	....	67	....	....
Pluto, coking coal, No. 8 bed	1.9	87	13	....	....	....	....
Cannel coal, No. 7 bed	.1	60	40	....	....	....	....
Saarbrücken.							
Camphausen, No. 3 bed	1.2	84	16	....	....	....	....
Upper Silesia.							
Gräfin Laura, Sattel bed	.4	....	60	5	30	....	5
Obernkirchen.							
Buckeburg, Walder	1.1	94	3	....	3	....	....
Habischtswald, lignite	.6	....	91	....	....	....	9
England.							
Ryhope, Hutton bed	.9	94	3	....	....	3	....

GAS FROM SAMPLES OF BELGIAN COALS.

Ghysen [a] discusses the results of tests of samples of two coals from Marcinelle-Nord mine, one series being taken from a depth of 3,100 feet in No. 12 shaft and another from the same bed at a depth of 2,920 feet in No. 11 shaft. The tests were made by Fontenille and Lecocq. There had been several strong outbursts of gas from the bed, one of which occurred at a depth of 2,920 feet, blowing out 95 tons of coal. The two shafts are three-fourths of a mile apart and are separated by a great fault; the deeper shaft is generally more gaseous than the other. Samples of about 17½ pounds each, in fragments about 0.6 cubic inch in diameter, were collected every morning, crushed with steel balls for one hour in a pulverizer hermetically tight, and tested twice, at intervals of four hours, in the afternoon. A series of 19 samples from No. 12 shaft yielded gas containing 69.1 to 84.65 per cent methane (mean, 74 per cent), with less than 1 per cent of oxygen and carbon dioxide, the remainder being nitrogen and air. A series of 12 samples from No. 11 shaft yielded gas containing 43.5 to 87.3 per cent methane. The volume of gas in each test was never less than 1½ that of the coal. The increase in quantity of gas given off in the four-hour interval between the two tests was inappreciable. The most important feature is the variation in the volume of gas given off under the same conditions by samples taken at the same hour and from the same place. By crushing a sample in two stages of half an hour each and drawing off the gas after each stage separately a greater total volume of gas was collected than after continuous crushing for an hour. For different samples the composition of the gas differed greatly, a variation that Ghysen believes was due to irregularities in escape of gas through cracks and also to differences in original vegetal composition. Gas was also lost in mining, such loss naturally being uneven. It was found, also, that from samples taken in the same vicinity the volume of gas given off in pulverization varied from two and one-half to five and one-half times that of the coal. Similar tests were made, also, of some samples which had been exposed to air for seven to nine months. In every case they gave off about 1½ volumes of gases, but the composition of these was peculiar in that gas from samples from shaft 11 contained from 9 to 14.75 per cent of methane or other combustible gases; the gas from samples from shaft 12 contained only 1.5 to 2.8 per cent.

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[a] Ghysen, Henri, Quelques considérations sur les dégagements instantanés de grisou: Rev. univ. des mines, ser. 3, vol. 59, 1902, pp. 1-61.

Arnould,[a] in his study of gas outbursts, found that some coal when placed in a receptacle gave off four times its volume of gas and believed that the amount in the solid coal underground must be greater.

Marsilly[b] found that a pressure of 75 pounds to the square inch did not prevent the issue of gas from coal samples, and the Austrian commission found that coal from which gas had been exhausted in a vacuum could not reabsorb as much as it held originally. Coal from the Albert mine at Saarbrücken yielded two to two and one-half volumes of gas.

GAS FROM SAMPLES OF AMERICAN COALS.

Tests made by Chamberlin[c] of the volume of gas given off by various coals yielded some interesting results, showing not only the variability in volume and in components, but the variations under different conditions. Under ordinary air pressure the Monongah (W. Va.) coal yielded 0.86 per cent of its volume of methane when powdered to 30-mesh size and only half as much at 10-mesh size. When the coal was placed in a vacuum, the yield was practically the same. Two other samples yielded much less. A sample of anthracite from No. 1 mine, at Nanticoke, Pa., gave off 3.1 volumes of gas in three weeks; during the fourth week a further volume of 0.8, which was nearly pure methane, was given off. The highest proportion of carbon dioxide found was 0.17 per cent of the total volume of gas liberated.

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[a] Arnould, G., Étude sur des dégagements instantanés de grisou dans les mines de houille du bassin Belge: Ann. trav. pub. Belgique, vol. 37, 1880, p. 9.

[b] Marsilly, —., Étude des principales variétés de houilles consommée sur le marché de Paris, [etc.]: Annales des mines, ser. 3, vol. 12, 1857, p. 360.

[c] Chamberlin, R. T., Notes on explosive mine gases and dusts, with special reference to explosions in the Monongah, Darr, and Naomi coal mines: Bull. 26, Bureau of Mines, pp. 17–39; reprint of U. S. Geol. Survey Bull. 383.

RATE OF ESCAPE OF GAS FROM COAL.

It has been shown that methane and other gases escape continuously from coal while it lies undisturbed underground, while it is being mined, and also for a long time after it has been mined. The rate of escape in general is variable but is without known relation to the mechanical or granular condition of the coal. Coal that had lost much gas in mining continued to evolve methane in the laboratory, one sample liberating three-fourths of its volume in two weeks and one and three-fourths volumes in five months.

Various investigations have shown that there is great variation not only in the total and relative volumes of methane given off by coal samples but in the rate of emanation as well. In general the methane is given off more slowly than the carbon dioxide, oxygen, or nitrogen, so that in the smaller volume of gases extracted in the later part of the test its percentage increased with some samples.

EFFECT OF CRUSHING.

That size of grain is also an important factor has been shown particularly by Chamberlin[a] who found the rate of emanation was increased by crushing the coal fine, by the addition of carbon dioxide, and by placing the sample in a vacuum. In his experiments the coal was broken and crushed to coarse powder in an air-tight receptacle connected with a vacuum pump. It is believed that little gas is lost in taking the coal sample from the mine and making the laboratory transfer. The crushing, however, opens a large proportion of pores and minute crevices and thus greatly increases the surface from which the gas is given off. Tests were made with samples under atmospheric pressure as well as in a vacuum. Some samples were pulverized for several hours to ascertain the time factor. A sample from the Monongah mine, West Virginia, was divided into two parts; one part was crushed to 10-mesh and the other to 30-mesh size, each part being tested separately. The results[a] were as follows:

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[a] Chamberlin, R. T. Op. cit., pp. 33–39.

Relative volumes of methane from 10-mesh and 30-mesh samples of coal.

No. of test.	Conditions of test.	Relative volume of methane to coal.	
		30-mesh sample.	10-mesh sample.
1	In vacuum nearly an hour	0.88	0.33
2	In vacuum short time, then in CO_2 at atmospheric pressure	.89	.38
3	In air under atmospheric pressure	.86	.41
4	In pure CO_2 under atmospheric pressure	.91	.44
5	In vacuum 3½ hours, then in CO_2 under atmospheric pressure	1.38	.57
6	In vacuum 4 hours, then in hydrogen and CO_2 under atmospheric pressure	1.39	.53

The last two experiments show that the gas does not escape rapidly and that time is an important factor. The experiments as a whole show that if the crushing is not delayed the methane emanation is practically the same whether coal is crushed in vacuum or under normal atmospheric pressure. The gas continues to escape as time passes. The amount immediately liberated also is independent of outside pressure.

Tests were made both in a vacuum and under full atmospheric pressure, and several trials were made to ascertain the time factor up to four hours. Two samples of Monongah coal crushed in vacuum gave the following results:[b]

Volumes and analyses of gas from coal crushed in vacuum.

No. of sample.	Relative volume of gas to coal.	Constituent.			
		Methane.	Carbon dioxide.	Air.	Nitrogen (excess).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1	0.10	39.65	2.90	48.18	9.27
2	.12	40.99	1.56	47.48	10.27

RATE OF ESCAPE FROM LUMP COAL.

In another test, lumps of coal were placed in a receptacle from which the air was exhausted in about 20 minutes, the diminution of pressure amounting to more than 29 inches. The air exhausted in 20 minutes from a vessel containing Monongah coal contained 0.002 volume of methane, whereas coal from the Naomi and the Mansfield mines gave only a trace of methane. A fourth sample from a gaseous part of the Monongah mine gave off 0.003 volume of methane. A sample of lumps of anthracite coal from No. 1 mine, Nanticoke, Pa., gave off 0.03 volume of methane in 20 minutes and 1.07 volumes in 7 days.

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[a] Chamberlin, R. T. Op. cit., pp. 21–22.

[b] Chamberlin, R. T. Op. cit., pp. 18, 19.

Chamberlin made an extended series of tests[a] to ascertain the rate of escape of gas from coal samples during a period of six months. The coal was stored in vacuum bottles and the gas pumped out at intervals for analysis. The volume of gas and rate of escape depended greatly on the size of the fragments. At the end of six months gas was still escaping from lump coal, whereas the liberation of gas from the crushed coal had nearly ceased. Samples of one crushed coal yielded 2.3 to 0. 9 volumes of gas, whereas lump samples of the same coal yielded only 0.5 to 0. 9 volume of gas. To investigate the volume of gas lost in handling the sample, coal was collected at the face in the mine and placed in cans, which were at once sealed. The gas in the cans was determined a week later, and a month later some of the sample that had been placed in vacuum bottles was tested. Bituminous coal from the Mansfield mine, Carnegie, Pa., gave off 0.55 volume of gas exclusive of nitrogen, and gas escaped more rapidly during the first few days. A sample of gaseous anthracite, however, showed a nearly uniform rate of escape of methane. The rates and percentages of methane emanation from various coals were as follows:

Rate of escape of methane from coal samples crushed to pass a 1-inch mesh and in a vacuum.

Mine.	Kind of coal.	Period of first exposure.	Relative volume of gas to coal (coal=1).	Methane in gas.	Period of second exposure.	Relative volume of gas to coal (coal=1).	Methane in gas.
				Per ct.			*Per ct.*
Monongah	Bituminous	3 weeks	0.06	35	4 weeks	0.07	67
Naomi	do	do	.11	55	do	.17	85
Mansfield	do	10 days	.25	82	10 days	.11	72
Nanticoke No. 1	Anthracite	1 week	1.06	87	1 week	.92	94

Mine.	Kind of coal.	Period of third exposure.	Relative volume of gas to coal (coal=1).	Methane in gas.	Period of fourth exposure.	Relative volume of gas to coal (coal=1).	Methane in gas.	Total period of exposure.	Total volume of gas to coal.
				Per ct.			*Per ct.*		
Monongah	Bituminous	10 weeks	0.10	76	9 weeks.	0.075	84	6 months	0.30
Naomi	do	do	.25	91	do	.18	88	do	.71
Mansfield	do	10 days	.11	84				30 days	.47
Nanticoke No.1	Anthracite	1 week	.84	94	1 week	.78	94		3.60

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[a] Chamberlin, R. T. Op. cit., pp. 24–31.

Gases other than methane were mainly air, nitrogen, and carbon dioxide. The rate of escape of nitrogen decreased with time, showing that the nitrogen was mainly from residual air that had given up its oxygen to the coal.

Deducting extra nitrogen the proportion of methane rose as high as 98 per cent for some samples; but usually it was between 80 and 95 per cent. The methane percentages were highest in the anthracite sample, which yielded but little carbon dioxide, whereas the bituminous coal from the Mansfield mine contained as much as 13 per cent of carbon dioxide.

Lump coal fresh from some mines continues to evolve gas enough to be lighted in a mine car. Morin [a] cites an instance in which air extracted from the center of a pile of freshly broken coal weighing 3 or 4 tons contained 16 to 26 per cent of methane.

RATE OF ESCAPE FROM PULVERIZED COAL.

In order to compare the rate of escape of gas from finely crushed coal with that from coarse lumps in the test by Chamberlin, just described, samples from other parts of the Monongah mine were crushed to pass through a 10-mesh sieve and then bottled in vacuum. The results were as follows:

Rate of escape of methane from coal crushed to 10-mesh and bottled in a vacuum.[a]

Sample.	Period of first exposure.	Relative volume of methane to coal (coal=1).	Proportion of methane in gas.	Period of second exposure.	Relative volume of methane to coal (coal=1).	Proportion of methane in gas.	Period of of third exposure.	Relative volume of methane to coal (coal=1).	Proportion of methane in gas.	Total period of exposure.	Total volume of gas to coal.
			Per ct.			*Per ct.*			*Per ct.*		
A.........	6 weeks	0.54	56	10 weeks	0.17	64	10 weeks	0.06	47	6 months	0.77
B.........	...do..	.53	63	...do...	.08	....	.....do...	.07	42	....	.68

[a] Results in round numbers.

In general the proportion of carbon dioxide steadily increased, finally reaching 15 per cent in sample A, and nearly 21 per cent in sample B. Provided that this coal was of the same character as the other, the comparison shows plainly that finely crushed coal gives off much more gas than lump coal; emanation starts more rapidly, and the proportion of methane is larger.

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[a] Morin, Léon, De l'influence des variations de la pression atmosphérique sur les dégagements de grisou: Annales des mines, ser. 10, vol. 16, 1909, pp. 385–487.

COMPARATIVE TESTS OF DIFFERENT SIZES.

A series of tests was made by Chamberlin [a] to determine the rate of escape of methane from coals of various kinds and especially the relative volumes from the same coal in small lumps and in powder. The results are given in figure 2, in which volumes of methane are shown by the vertical scale and the time in weeks by the horizontal scale, the two scales having only an arbitrary relation to each other.

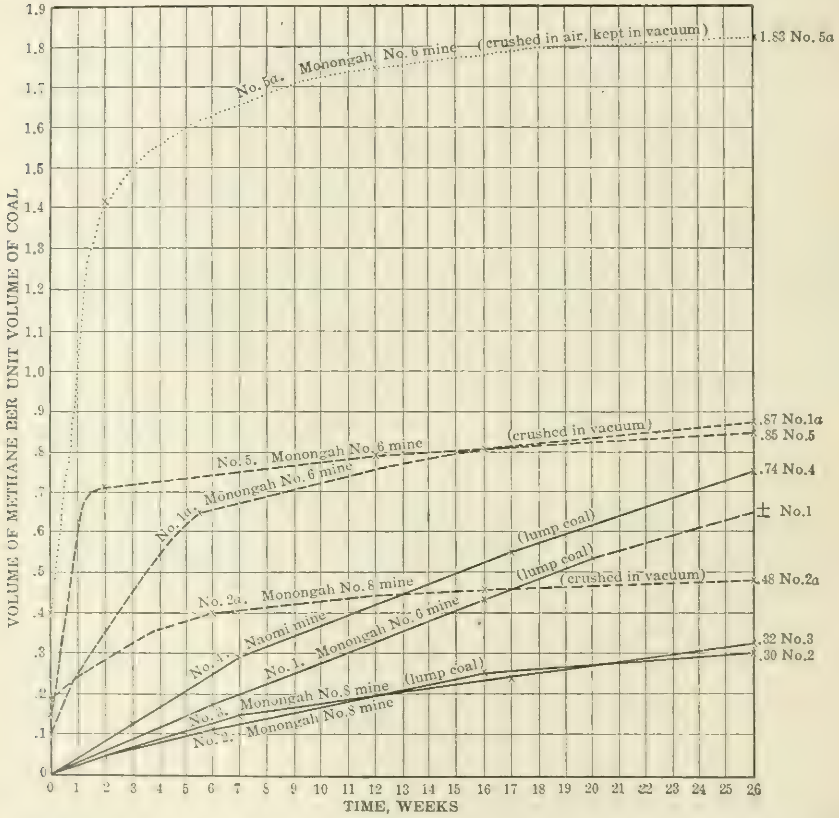

FIGURE 2. Diagram showing rate of escape of methane from coal under various conditions (after R. T. Chamberlin). —— coal size of marbles; — — — coal crushed in vacuum; .... coal crushed in air; ×, methane determined. Nos. 1 and 1*a*, same coal; Nos. 2 and 2*a*, same coal; Nos. 5 and 5*a*, same coal.

METHOD OF TESTING.

Samples 1 and 1*a* were taken from the Monongah No. 6 mine. No. 1 was tested in lumps. No. 1*a* was crushed in a vacuum and then replaced in a vacuum bottle. Samples 2 and 2*a* were obtained from the Monongah No. 8 mine. The first was in lumps, the second was crushed in a vacuum and placed in a vacuum bottle. No. 3, from the east return airway of the Monongah No. 8 mine, and No. 4, from the most gaseous part of the Naomi mine, were lump samples. Samples 5 and 5*a* were from the Monongah No. 6 mine. No. 5 was crushed in a vacuum and at once placed in a vacuum bottle, and No. 5*a* was crushed in air before being placed in a vacuum bottle. The samples were kept in the vacuum bottles for half a year, gas being pumped out at intervals. Samples 1*a*, 2*a*, 5, and 5*a* were crushed to pass through a No. 10 sieve. The volumes of gas liberated in crushing are also included in the volumes shown in figure 2, so that curves 1*a*, 2*a*, 5, and 5*a* start with the quantity liberated.

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[a] Chamberlin, R. T., Op. cit., pp. 33–36.

It is believed that the proportion of gas lost in transferring the powder to vacuum bottles was very small. However, some gas was lost in mining the coal and in breaking it to lumps; also, the gas that accumulated in the cans in five weeks or more escaped, so that the original gas content can only be surmised.

CONCLUSIONS.

The full-line curves in figure 2, representing the methane emanation from lump coal, show that liberation of gas from lump coal even in a vacuum is slow and regular and may continue indefinitely. Sample 1 particularly showed indefinite liberation of methane. Two of the same coals crushed (samples 1*a* and 2*a*), as well as other crushed coals (5 and 5*a*), show a much more rapid rate of emanation at the outset, followed by rapid decline. The methane in crushed samples 1*a* and 2*a* was not tested until the sixth week, so that these curves as drawn have too low an initial gradient. This series of tests shows clearly that methane escapes more freely and in larger volume from crushed coal, but that the supply more slowly emitted by the lumps would in time equal that from the powder. Therefore, the extent to which the "pores" of the coal are opened affects the rate of emission, but not the ultimate volume of the gas liberated, so it is not a matter of volume of gas liberated in a given time, but of liberation of all the gas in sufficient time. Chamberlin further summarized the conclusions drawn from these results as follows:

1. Reduction of pressure removes gases from coal slowly—a matter of weeks and months.
2. Finely powdered fresh coal gives off more methane during six months in a vacuum than the same amount of lump coal subjected to the same conditions. But, presumably during a much longer period of time, approximately the same volume of gas should be expected to come off from either type of coal.

3. Reduction of pressure for only a few hours or even a few days is far less effective in extracting the entrapped gas than crushing the coal, either in a vacuum or under barometric pressure.

4. Crushing coal to a certain degree of fineness yields approximately the same volume of methane, whether the operation is performed in a vacuum or in an atmosphere of air or carbon dioxide.

5. Crushing the coal to the degree of fineness of which the crusher is capable removes only a minor proportion of the free gas stored within the coal, for Monongah coal already crushed either in vacuum or under full atmospheric pressure yielded more methane during two weeks in a vacuum than was liberated during the crushing.

The conclusions signify that old coal workings and faces continue to give off gas.

VARIATION IN VOLUME FROM DIFFERENT COALS.

TESTS OF VARIOUS AMERICAN COALS.

Porter and Ovitz [a] have recently tested coals of various kinds from several places in the United States. They supplemented Chamberlin's work, and found that methane and small amounts of carbon dioxide are given off by coal for an extended period under ordinary atmospheric pressure, the amount of gas and its rate of escape being nearly the same as when the coal is kept in a vacuum. They ascertained, also, that oxygen was absorbed rapidly by fresh coal, but in quantities too small to account for the volume of carbon dioxide liberated, if the latter be assumed to result from slow combustion of the coal. They found great variation in the proportion of methane liberated. A Kentucky cannel coal yielded only a trace of methane in nine months, whereas coal from Harrisburg, Ill., gave off one-fourth of its volume in four days, and a coal from Monongah, W. Va., yielded one-third of its volume in the same time. A sample of Pocahontas (Va.) coal yielded little gas, yet mines in the western part of the Pocahontas district contain much gas at times. They found, in general, that at first gas escapes rapidly from coal, then in less and less amounts, with complete cessation in 3 to 18 months.

METHOD OF TESTING.

Porter and Ovitz took about 22 pounds of coal from the clean fresh face, crushed it to pass a ½-inch screen, and placed it in a crated 5-gallon glass bottle, quickly stoppered with a rubber stopper having a sealed tube in it. This operation occupied 50 to 80 minutes. They estimate that one-fourth of the gas escaped in crushing the coal, as shown by Chamberlin, and one-half to 1½ volumes on continued exposure to air. On arrival at the laboratory some of the air in the bottle was drawn through the tube in the stopper and analyzed. The sample was then allowed to stand several months at a temperature of 54° to 88° F. The bottles containing the Pocahontas, Va., and Benton, Ill., coal samples were connected with an oxygen supply and the samples of Sheridan, Wyo., and Harrisburg, Ill., coals with an air supply; the air or oxygen admitted and the gas withdrawn were measured and analyzed. The gas was drawn at intervals from the Pocahontas coal so that at times some pressure may have developed which might have retarded gas emanation. The other samples were tested by withdrawing air from the bottle at intervals. The Harrisburg coal showed gradual diminution of escape of methane, long-continued absorption of oxygen, and a steadily increasing liberation of carbon dioxide, results that seemingly indicate that carbon dioxide is held more tenaciously than the other gases. The coals giving the smaller amounts of methane yielded the most carbon dioxide at the start. The coal from Rock Springs and Sheridan, Wyo.; Paintsville, Ky.; Monongah, W. Va.; Harrisburg, Ill.; and Connellsville, Pa., were not tested long but they gave rapid liberation of gas at the start.

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[a] Porter, H. C., and Ovitz, F. K., The escape of gas from coal: Tech. Paper 2, Bureau of Mines, 1911, 14 pp.

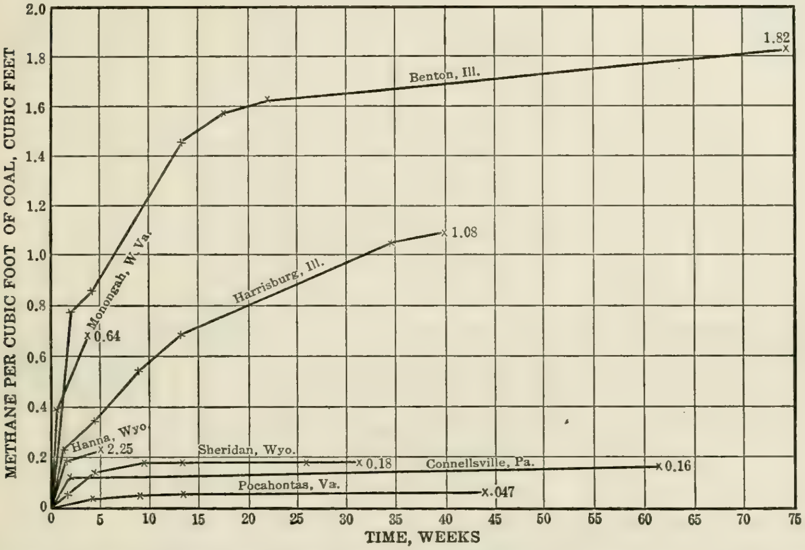

FIGURE 3.—Diagram showing rate of escape and volume of methane from 8 samples of American coals (after Porter and Ovitz). Time begins 1 hour after mining, hence methane given off in mining is not included.

RESULTS OF TESTS.

The results of these tests are given in the table following and some of them are shown in figure 3.

Rate of escape of methane and carbon dioxide from coals in small lumps (1 inch).

Source and kind of sample.	Period of time.	Volumes of gas relative to volume of coal (coal=1).		Remarks.
		Methane.	Carbon dioxide.	
Pocahontas, Va., No. 3 bed, Baby mine, semibituminous coal.	First month	0.032	0.002	Oxygen admitted as fast as absorbed and gases withdrawn at intervals.
	Second month	.009	.000	
	Third month	.002	.0002	
	Fourth to ninth month	.004	.0016	
	Tenth month	.000	.003	
	Total in 10 months.	.047	.006	
Harrisburg, Ill., No. 5 bed, O'Gara No. 9 mine, bituminous coal.	First 4 days	.218	.001	Under flow of air into center and out of top to reservoir.
	Remainder of first month.	.122	.000	
	Second month	.217	.003	
	Third month	.125	.000	
	Fourth to eighth month.	.372	.030	
	Ninth month	.029	.019	
	Total in 9 months.	1.083	.054	
Sheridan, Wyo., No. 9 bed, Dietz No. 2 mine, subbituminous coal.	First week	.075	.025	Do.
	Eighth to thirtieth day	.078	.008	
	Second month	.031	.050	
	Third month	.000	.060	
	Fourth to sixth month	.000	.158	
	Seventh month	.000	.067	
	Total in 7 months.	.184	.368	
Benton, Ill., Hart-Williams mine, bituminous coal.	First half month	.763	.010	Connected with oxygen supply at top of bottle and flowing out from below into a reservoir.
	Second half month	.113	.000	
	Second and third months.	.577	.019	
	Fourth month	.107	.018	
	Fifth month	.065	.007	
	Sixth to seventeenth month.	.196	.079	
	Total in 17 months.	1.821	.133	
Rock Springs, Wyo., Rock Spring bed, No. 1 mine, bituminous coal.	First 22 days	.015	.075	
	Twenty-third to thirty-first days.	....	....	
	Total in 1 month	....	.075	
Hanna, Wyo., lower bed, No. 2 mine, bituminous coal.	First 10 days	.192	.025	
	Eleventh to thirty-first days.	.033	.002	
	Total in 1 month	.225	.027	
Monongah, W. Va., Pittsburgh bed, No. 2 mine, bituminous coal.	First 4 days	.390	.000	
	Fifth to thirty-first days.	.251	.005	
	Total in 1 month	.641	.005	
Paintsville, Ky., Flambeau mine, cannel coal.	9 months	None.	.035	
Connellsville, Pa., Pittsburgh bed, Leisenring No. 1 mine, bituminous coal.	First day	....	....	
	Second to eleventh days.	.122	.006	
	Twelfth to four hundred and twenty-seventh days.	.038	.007	
	Total in 14 months.	.160	.013	

TESTS OF ILLINOIS COALS.

An investigation of occluded gases in Illinois coals by Parr and Barker [a] gave results that throw additional light on the volume of gas and the conditions of its emanation.

Samples were collected from the working faces. Each sample was divided into two parts; one was placed in a jar in air, and the other was kept under water in a jar. The samples were allowed to stand for seven months, with the following results:

Volumes of methane given off in seven months by Illinois coals.

Number of sample.	Mine.	Relative volume of methane to coal (coal=1).	
		Dry coal.	Coal under water.
1	Lebanon	0.00	0.036
2	Bennett	.00	.017
3	O'Fallon	.66	.147

The percentages of methane in the gas given off were as follows: No. 1, wet, 56; No. 2, wet, 35.4; No. 3, dry, 11.8; and No. 3, wet, 90.3. Small amounts of carbon dioxide were given off by Nos. 2 and 3, dry.

Tests to determine the effect of oxygen absorption were made with some samples that had been partly air-dried after having been kept sealed 10 months. They were placed in open jars. Two samples were from the Sangamon mine at Springfield, one was from the Chicago & Big Muddy mine near Marion, one from the Davis mine near Duquoin, one from the Suburban mine, near Belleville, one from O'Fallon mine No. 2, one from O'Gara mine No. 8, near Eldorado, and one from the Squirrel Ridge mine near Herrin.

Only the two latter gave off methane, the coal from the No. 8 mine yielding 0.38 volume, or a little more than one-third, and the Squirrel Ridge coal 0.17 volume, or a little less than one-fifth.

As it was realized that considerable methane was lost in collecting the samples of broken fragments at the face of workings, some fresher material was obtained by taking drillings from shot holes. The drillings were run into a flask with suitable tubes, sealed at once, taken to the laboratory with the least possible delay, and the gas removed with a mercury air pump. A second extraction of gas was made several days later. The results follow.

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[a] Barker, Perry, The occluded gases in Illinois coals: Illinois Geol. Survey Bull. 14, 1908, pp. 204–210: Trans. Am. Inst. Min. Eng., vol. 40, 1909, pp. 24–31; Parr, S. W., and Barker, Perry, The occluded gases in coal: University of Illinois Bull. 32, vol. 6, 1909, 28 pp.

Volumes of methane from drillings of Illinois coals.

Mine.	Town.	Relative volume of methane to coal (coal=1).		Proportion of methane in gas.	
		First test.	Later test.	First test.	Later test.
				Per cent.	*Per cent.*
Sangamon	Springfield	0.162	0.081	22.53	59.59
Squirrel Ridge	Herrin	.252	.254	21.79	86.37
Clifford No. 8	do	.506	.294	32.44	70.93
Peabody No. 3	Marion	.021	.001	2.12	1.00
Westville No. 44		.262	.255	23.17	19.26

In tests of some laboratory samples of the same coal 2 years old considerable gas but no methane was obtained.

Another test was made of drillings from a 5½-foot hole in the Westville mine, the drillings from the first 2½ feet of the hole being kept separate from those of the last 3 feet. The tests were in two sets; one set was kept in air for 7 days and the other in vacuum for 13 days. The volumes and percentages of methane released were as follows:

Volumes of methane from coal drillings from Westville mine.

Source in drill hole.	7-day test.		13-day test.	
	Relative volume of methane to coal(coal=1).	Proportion of methane in gas.	Relative volume of methane to coal(coal=1).	Proportion of methane in gas.
		Per cent.		*Per cent.*
First 2½ feet	0.149	11.7	0.030	43.7
Last 3 feet	.262	23.2	.029	19.3

The percentage of carbon dioxide in the gas was 7.57 and 12.09 in the two 7-day tests, and 33.33 and 32.09 in the 13-day tests.

EFFECT OF OXIDATION.

The early experiments of Von Meyer [a] showed that although coal lost most of its gases, especially methane, when partly exposed, a considerable amount of gas was evolved or could be extracted for years afterwards. His method was to take a sample of nut-sized pieces, place them in a flask, cover them with freshly boiled water, and extract the gases by heating. The following results were obtained from German coals. Samples 1, 2, and 3 were from Zwickau and samples 4 to 9 were from Bochum.

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[a] Von Meyer, E., Ueber die in Steinkohlen eingeschlossenen Gasse: Jour. prakt. Chemie, vol. 113, 1872, pp. 144–183.

Comparative volumes of gases from fresh and weathered coals.

No. of sample.	Condition of sample.	Relative volume of gas to coal (coal=1).	Composition of gas.				
			CH_4.	C_2H_4 and C_2H_6.	CO_2.	O.	N.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	Fresh	0.285	71.90	....	2.42	2.51	23.17
	Weathered 5 years	.14	3.17	20.08	16.70	4.90	55.15
2	Fresh	.40	51.40	....	.60	.00	48.00
	Weathered 5 years	.10	15.88	23.31	7.62	2.44	50.75
3	Fresh	.19	45.00	....	4.02	.62	50.36
	Weathered 1½ years	.14	73.16	....	2.25	.72	23.89
4	Fresh	.38	16.65	....	4.87	2.66	75.82
	Weathered 5 years	.32	7.40	....	11.12	2.88	78.60
5	Fresh	.44	31.57	....	4.82	1.99	60.62
	Weathered 5 years	.32	3.31	....	7.68	2.24	86.77
6	Fresh	.32	25.19	....	2.18	2.12	70.51
	Weathered 5 years	.31	6.57	....	15.84	3.06	74.53
7	Fresh	.41	30.25	....	1.30	1.60	66.85
	Weathered 5 years	.29	11.12	....	4.35	3.35	81.18
8	Fresh	.33	5.70	....	3.72	.39	90.19
	Weathered 1½ years	.27	.00	....	8.49	3.57	87.94
9	Fresh	.41	10.65	....	2.02	.90	86.43
	Weathered 1 year	.30	3.43	....	2.15	3.14	91.28

A series of tests that were made by Parr and Barker [a] to determine the effect of oxidation of coal, showed considerable variation in the amount of methane given off. All three samples were taken from the Squirrel Ridge mine.

Volumes of methane from coal from Squirrel Ridge mine.

No. of test.	Condition of sample.	Conditions of test.	Relative volume of methane to coal (coal=1).	Proportion of methane in gas.
				Per cent.
1	Partly air-dried sample 2 years old.	Air from sealed container in which sample had been kept for two years.	0.166	2.2
2	.....do	Sealed in air 2 days and air and gas pumped off.	.000	.0
3	Fresh drillings	Sealed 14 days and air and gas pumped off.	.252	21.8
4	.....do	Sample in vacuum 12 days after test 3 and gas pumped off.	.253	86.4
5	.....do	Sample sealed in air for 7 days after test 4.	.112	14.1

Tests were also made of samples taken from this and other mines two years before. The samples were quartered, reduced to buckwheat size, and air dried, and although they yielded considerable nitrogen, oxygen, and carbon dioxide, they gave off no methane· The proportion of carbon dioxide varied from 2 to 8 per cent in most of the first tests to 18 to 55 per cent in the later tests, one sample from Springfield yielding as much as 80.5 per cent. Some of the material was from working faces not far from long-standing exposures, the mines having been idle some time.

Screenings from the Westville mine that were 15 and 2 months old yielded no methane in the first test, but two samples of gas removed by vacuum in later tests contained 0.002 and 0.008 volume, respectively. Two-months-old screenings from the Sangamon mine near Springfield, yielded 0.009 volume of methane in the first test and 0.035 volume in a second test. These screenings had been stored outside of the mine. A sample of outcrop coal near Marion, exposed a year, gave 0.006 volume of methane in the first test and 0.001 volume additional in later tests; the proportions of methane in gases given off in the two tests were 0.54 and 1.05 per cent, respectively.

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[a] Parr, S. W., and Barker, Perry, The occluded gases in coal: University of Illinois Bull. 32, vol. 6, 1909, pp. 23-26.

AMOUNT OF METHANE IN MINE AIR.

Much information is on record as to the volume of gas contained in the return air of coal mines. Many tests have been made in mines in Europe, some of them for protracted periods. The results of the author's investigations of numerous mines in the Pennsylvania and Illinois coal fields, which are presented in Parts II and III of this bulletin, show great variation in the total volume of methane emanation from different mines and also from different beds and workings in the same mine. Some parts of mines and some mines that have the most marked manifestations of gas from blowers and local accumulations show smaller total methane emanation than those where the gas is given off generally and continuously.

FACTORS AFFECTING VOLUME.

The proportion of methane in the return air of a mine depends not only on the total volume of gas given off, but also on the volume of air used for ventilation; therefore the most useful figures for comparison are those indicating the volume of methane. Even when the air current is of uniform volume from day to day, the usual condition, the proportion of methane varies, and this variation is sometimes closely related to the amount of coal mined, diminishing in marked degree during a cessation of mining, even for a day. Usually, however, the variation in the volume of methane in the return air is due directly to the variation in the quantity given off by the coal from place to place, increasing as gaseous areas are opened and diminishing as they are drained. Squeezes and outbursts are also important factors, as shown in previous pages. There has been considerable discussion as to what is a gaseous mine, and most classifications proposed have been based on the amount of methane and carbon dioxide in the main returns. This is not a safe basis of comparison, as the danger from gas in a mine depends less on the steady outflow, even if it is large, than on the liability to outbursts and large volume given off in the fresh chambers and headings. Most authorities agree that more than 2 per cent of methane in the return air is an indication of a very gaseous mine.

In most beds of coal there are variations in texture and hardness and in the trend and number of joint planes large and small. The water content in the pores and crevices also varies greatly in different places. These factors all have important bearing on the variation of the volume of methane contained in coal and the rate of its emanation. The more porous coal may or may not contain a larger volume, but it gives off methane more rapidly. The difference between the total volume of gas given off by the coal and the rate of emanation is usually overlooked in discussing the gas problem. Ordinarily, the coal is regarded as most gaseous that gives the most gas in fresh headings while it is being uncovered, but a more compact coal may contain more gas and give it off gradually and for a long time.

The return air in many mines regarded as nongaseous contains only 0.01 per cent or less of methane, whereas in some gaseous mines main return-air currents of 200,000 cubic feet per minute carry 2 per cent or more of methane. Mention has already been made of mines near Wilkes-Barre, Pa., that discharge 2,000 to 3,000 cubic feet of methane a minute, or nearly 3,000,000 cubic feet in 24 hours; the air in the main upcasts of these mines carries 1 to 2 per cent of methane.

PERCENTAGES IN PRUSSIAN MINES.

Schöndorff [a] has given some interesting figures of percentages of methane in returns in some Prussian mines. In several mines in the Saarbrücken basin, the methane content ranged from 0.05 to 1.46 per cent; in the Aachen basin, from 0.65 to 1.56 per cent; in the lower Rhenish Westphalia basin from 0.002 to 1.428 per cent; and in the lower Silesian basin from 0.27 to 0.92 per cent. He gives the following figures:

Analyses of air in returns in coal mines in Saarbrücken basin, Prussia.

Mine.	Composition of mine air.			
	Methane.	Carbon dioxide.	Oxygen.	Nitrogen.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Albert, east district	1.39	0.28	20.19	78.14
Albert, west district	.65	.18	20.50	78.67
Van der Heydt, Amelung bed	.18	.12	20.40	79.30
Van der Heydt, Beust bed	.36	.46	19.62	79.56
Reden, east district	.57	.43	20.38	78.62
Reden, west district	.82	.43	20.10	78.65
Friedricksthal, small bed	.31	.24	20.38	79.07
Friedricksthal, overlying bed	.19	.20	20.69	78.92
Dudweiler, shaft 2	.70	.25	19.76	79.29
Dudweiler, shaft 1	1.08	.09	19.71	79.12
Salzbach, main return	.15	.40	20.43	79.02
Altenwald, Nos. 5 and 6 levels	.17	.41	20.81	78.61
Altenwald, No. 4 level	.30	.87	20.00	78.93
Altenwald, Nos. 1, 2, and 3 levels	.12	.46	20.14	79.28
Heinitz, Nov. 10, 1873	.13	.53	20.10	79.24
Heinitz, Aug. 18, 1874	.18	1.00	19.28	79.54
Heinitz, Sept. 20, 1875	.25	.70	19.40	79.65
Heinitz, Sept. 26, 1875	.13	.45	19.84	79.58
Dechen, east return	.14	.43	19.53	79.90

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[a] Schöndorff, A., Untersuchung der ausziehenden Wetterströme in den Steinkohlenbergwerken des Saarbrücken: Zeitschr. Berg-Hütt.-Salinenwesen, vol. 24, 1876, pp. 75–125; Chemische Untersuchung von Grubenwettern in Preussischen Steinkohlenbergwerken: Zeitschr. Berg-Hütt.-Salinenwesen, vol. 31, 1883, pp. 435–445; vol. 32, 1884, pp. 509–519.

Some of the results obtained by Schöndorff[a] in testing the methane content in the return air of several of these mines for the Prussian Fire Damp Commission some years later are as follows:

Volumes of methane in return air of different mines.

Mine.	Volume of air delivered per minute.	Proportion of methane in air.	Volume of methane delivered in 24 hours.
	Cubic feet.	*Per cent.*	*Cubic feet.*
Albert mine, east district	17,000	1.39	340,100
Albert mine, west district	15,610	.65	145,700
Van der Heydt mine, Amelung bed	34,550	.18	89,060
Van der Heydt mine, Beust bed	14,730	.36	76,120
Salzbach mine	18,680	.145	38,980
Altenwald mine, Nos. 5 and 6 levels	21,920	.165	52,080
Altenwald mine, Nos. 1, 2, and 3 levels	37,080	.12	61,980
Altenwald mine, No. 4 level	13,040	.30	56,920
Heinitz mine	27,990	.25	99,760

The total daily volumes of methane from several especially fiery mines were as follows:

Daily volumes of methane from fiery mines.

	Cubic feet per day.
Neu-Iserlohn mine, No. 2 shaft, Lower Rhenish Westphalia	897,600
Neu-Iserlohn mine, No. 1 shaft, Lower Rhenish Westphalia	305,000
Westphalia mine, Kaiserstuhl shaft, near Dortmund	503,700
Albert shaft, Saarbrücken	330,000
Gouley-Gemeinschaft-Königisgrube, Aachen	295,000±
Friedenshoffnung mine, southern section, lower Silesia	256,500
Schaumburger mine, No. 3 shaft, Wealden	280,000±

PERCENTAGES IN AUSTRIAN MINES.

The Austrian commission[b] made analyses of the return air in many mines and obtained a great variety of results. One of the most important series reported is from the very gaseous mines of the Karwin-Ostrau district. The results are given in round numbers in the following table:

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[a] Report of the Prussian Fire Damp Commission (translation); Trans. Fed. Inst. Min. Eng., vol. 4, 1893, p. 639.

[b] Atkinson, W. N., Digest of report of the Austrian Fire Damp Commission: Trans. Fed. Inst. Min. Eng., vol. 3, 1891-1892, p. 533; Annales des mines, ser. 9, vol. 1, 1892, p. 343.

Results of analyses of return air in mines in Karwin-Ostrau district, Austria.

Source of sample.	Composition of sample.		
	Methane.	Carbon dioxide.	Oxygen.
Gabrielle mine.	*Per cent.*	*Per cent.*	*Per cent.*
Returns from Nos. 12, 25, and 26 beds	1.77	0.06	19.61
Returns from No. 23 bed	1.25	.14	20.27
Average of the 4 returns	1.52	.15	19.87
H. Larisch mine, Karwin East.			
Returns from Nos. 18 and 19 beds	1.90	.12	19.54
Returns from No. 8 bed (flat district)	.83	.18	19.60
Average of 4 returns	1.62	.13	19.53
Bettina mine, Dombrau.			
Charles bed, steep dips	3.53	.10	19.72
Ignatius bed, steep dips	.68	.14	19.64
Average of 6 returns	1.72	.10	19.87

PERCENTAGES IN RUSSIAN MINES.

Kotsowsky[a] has given the results of a series of analyses of return air in the Donetz basin in Russia. The figures vary greatly as to components, the methane ranging from 0.13 to 2.93 per cent and the carbon dioxide from 0.18 to 1.36 per cent. In the central pit of the Youse mines the methane ranged from 0.32 to 2.50 per cent, and in No. 10 of the Rikowsky mines the air from one gallery carried 2.93 per cent of methane, whereas air at the working face in mine No. 14 contained only 0.13 per cent. The main upcast of the Usine pit carried 0.22 per cent of methane.

PERCENTAGES IN MINES OF SCOTLAND.

Gray[b] has given 85 analyses of return air from representative coal and shale mines in Scotland. The depths ranged from 36 to 2,221½ feet, and the air currents had volumes of 1,200 to 46,860 cubic feet a minute, some of them being total returns and others splits. Most of the coal-mine samples contained 0.05 to 0.5 per cent of methane, the content varying without relation to depth, except that some of the very shallow workings were less gaseous than deeper ones. Returns from deep workings in Fifeshire, however, showed no trace of methane. The largest volume of methane was in the main return from the Diamond mine, which carried 185 cubic feet a minute. In general, the shale mines gave off somewhat less methane and carbon dioxide, the volume of methane in the most gaseous return being 93 cubic feet a minute. The carbon-dioxide content was as high as 1 per cent in more than half of the returns.

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[a] Kotsowsky, N., La composition de l'air des mines dans le bassin du Donetz: Rev. univ. des mines, 3d series, vol. 31, 1895, pp. 50-166. Abstracted in Col. Guard, vol. 70, Nov. 8, 1895, pp. 890-891.

[b] Gray, Thomas, Analyses of samples of air from representative mines in Scotland: Trans. Inst. Min. Eng., vol. 39, 1909-1910, pp. 305-312.

RELATION OF VOLUME OF METHANE TO AMOUNT OF COAL MINED OR EXPOSED.

INVESTIGATION IN SAARBRÜCKEN BASIN, GERMANY.

As the proportion of methane in coal is variable, there is great variation in the amount given off in mining and in preparing coal. An extensive investigation of this branch of the subject was made in the Saarbrücken basin,[a] Germany. Twenty-three mines were examined and 652 analyses made. The volume of methane varied from 16½ to 1,060 cubic feet per ton of coal mined, or from one-half to 30 times the volume of the coal, and in one case the volume of gas was 2,160 cubic feet per ton. The methane emanation from the 23 mines varied from 8,870 to 732,566 cubic feet a day, and the total in a year was nearly 2⅕ billion cubic feet, or 44,000 tons of methane.

EMANATION FROM MINES NEAR WILKES-BARRE, PA.

Several mines in the anthracite region near Wilkes-Barre, Pa., producing about 2,000 tons of coal a day, each give off 2,000 to 3,000 cubic feet of methane per minute or 1,500 to 2,500 cubic feet per ton of coal mined, and the rate of emanation was not diminished greatly after mining had ceased for 30 days. Other mines, however, working the same beds and producing an equal tonnage, give off only 20 to 100 cubic feet a minute or 15 to 75 cubic feet per ton of coal mined. The latter, however, are shallower mines, and the coal may have contained originally as much gas as in the deeper part of the basin.

EMANATION FROM MINES IN SAXONY.

Winkler[b] has presented a series of interesting analyses indicating the difference between volume and composition of the ingoing and the outcoming air used in the ventilation of some mines in Saxony. The following is a partial statement of the results:

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[a] Anon. Quantité de methane (grisou) dégagée par les charbonnages du bassin de Saarbrücken: Rev. univ. des mines, ser. 3, vol. 33, 1896, p. 344: Zeitsch. Berg- u. Hutten, vol. 43, 1895; Eng. and Min. Jour., vol. 61, 1896, p. 517.

[b] Winkler, C. Die chemische Untersuchung der bei verschiedenen Steinkohlengruber Sachsens ausziehenden Wetterströme und ihre Ergebnisse: Jahrbuch Berghütten in Sachsen, 1882, pp. 65–84.

Composition and volume of constituents of return air and intake air in coal mines in Saxony.[a]

Mine.	Total volume.	Methane.	Carbon dioxide.	Oxygen.[b]	Nitrogen.	Moisture.
	Cubic feet.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
Lugau:						
Upcast	8,500	9	41	1,514	6,652	296
Intake	7,270	....	3	1,514	5,696	61
Difference	1,230	9	38	....	956	235
Bockwa-Hohndorf:						
Upcast	16,365	25	21	3,046	12,584	684
Intake	14,665	....	6	3,046	11,488	123
Difference	1,700	25	18	....	1,096	561
Deutschland:						
Upcast	6,690	9	8	1,209	5,236	226
Intake	5,575	....	2	1,209	4,315	47
Difference	1,115	9	6	....	921	179
Brueckenberg:						
Upcast	9,583	25	97	1,721	7,412	328
Intake	8,283	....	3	1,721	6,489	70
Difference	1,300	25	94	....	923	258
Oberhohndorf:						
Upcast	6,625	5	23	1,229	5,157	211
Intake	5,917	....	2	1,229	4,637	49
Difference	708	5	21	....	520	162
Van Arnim:						
Upcast	19,866	3	205	3,717	15,489	450
Intake	17,894	....	7	3,717	14,018	150
Difference	1,972	3	198	....	1,471	300
Zaukeroda:						
Upcast	7,548	1½	33	1,447	5,849	218
Intake	6,965	....	3	1,447	5,457	58
Difference	583	1½	30	....	392	160
Von Burgks:						
Upcast	13,882	17	39	2,584	10,816	426
Intake	12,149	....	5	2,584	9,458	102
Difference	1,733	17	34	....	1,358	324
Hainichen:						
Upcast	9,557	4	259	1,762	7,727	305
Intake	8,479	....	3	1,762	6,643	71
Difference	1,078	4	256	....	584	234

[a] Results are in round numbers per minute.
[b] It is not known why the amount of oxygen is the same in upcast and intake.

RESULTS OF AUSTRIAN INVESTIGATION.

The Austrian commission[a] found that in districts containing much gas the emanation of methane averaged 7,469 cubic feet per ton (21 to 22 cubic feet) of coal mined, whereas in the areas most free from gas the average was 519 cubic feet of methane per ton mined. The effect of the amount of coal mined was evident, but the volume of methane did not vary in direct ratio with it and a variation in the tonnage had to continue for some time to have much effect on the volume of methane. The relation in the Tiefbau mines is shown in figure 13.

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[a] Report of Austrian Fire Damp Commission: Abstract, Trans. Fed. Inst. Min. Eng., vol. 3, 1892, p. 534.

EMANATION FROM PRUSSIAN MINES.

The Prussian commission[a] found that 357 to 2,400 cubic feet of gas was given off per ton of coal mined. Chesneau found 1,377 cubic feet at the Herin mine at Anzin and 883 cubic feet at the Rouchamp mine. In a Westphalian mine it was found that in a bed giving off gas at a moderate rate and without blowers the volume emitted was closely proportionate to the area of freshly exposed coal surface. From his experience in English mines, Thomas was convinced that most of the gas in freshly exposed coal is given off in the first three or four hours.

The following figures have been given by Hilt [b] as to the methane given off per ton in mining coal in the Gemeinschaft and the Ath-Gouley mines:

	Cubic feet per ton.
Gemeinschaft, return 2	1,060 to 1,152
Ath-Gouley, return 1	2,171 to 3,360
Gemeinschaft, lower workings	409 to 632
Gemeinschaft, Meister bed	2,470 to 2,640

The relation of gas emanation to the area of coal exposed is well illustrated [c] in the Gemeinschaft mine in the Grosslangenberg bed which is gaseous throughout. In the anthracite part much of the gas comes from the sandstone roof and a gas emanation may last 10 years, beginning generally with a roof fall. The area is divided by a fault, east of which the bed is "flame" coal, where most of the gas drains off in three years. In 1882 the anthracite workings of this bed gave off 200,000 cubic feet of methane a day. The area of anthracite exposed by workings was 3,300,000 square feet, and for every 1,000 square feet of this surface 60 cubic feet of methane was emitted daily, equal to 219,000 cubic feet in 10 years. If the entire thickness of coal and sandstone be taken as 40 feet, for each cubic foot of material there must have been 6 cubic feet of gas to have sustained this emanation.

In the "flame" coal district, where the daily volume of methane was 130,000 cubic feet, the area of surface exposed in three years of mining was 2,100,000 square feet. The thickness of material holding gas is about 4¾ feet and with methane emission of about 60 cubic feet for each 1,000 square feet of area, the total volume of methane from the entire mass of 65,700 cubic feet would be 13.8 cubic feet per cubic foot of coal. This is believed to indicate that in the "flame" coal district the gas in the coal must have had an average pressure of 207 pounds to the square inch.

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[a] Hilt, C., Bericht über Versuche betreffend den Einfluss des wechselnden Luftdruckes auf die Entwickelung des Grubengasses: Zeitschr. Berg- Hütt.- Salinenwesen, vol. 34, 1886, pp. 72–90. Translation by M. Simon, Bull. Soc. l'indus. min., ser. 3, vol. 1, 1887, pp. 595, 625; abstracted in Trans. Fed. Inst. Min. Eng., vol. 4, 1893, pp. 645–646.

[b] Hilt, C., Op. cit., pp. 78, 600–615.

[c] Report of Prussian Fire Damp Commission (Translation): Trans. Fed. Inst. Min. Eng., vol. 4, 1893, pp. 639–641.

In October, 1882, in the Westphalia mine near Dortmund, the workings connected with the Kaiserstuhl shaft, which were in a fiery bed, had an exposed surface of 110,000 square feet.[a] It was found that for every cubic foot of solid coal removed 9.7 cubic feet of gas was produced, or 875 cubic feet for every ton mined, and 81 cubic feet of methane for every square foot of coal surface exposed. On the other hand, on January 30, 1884, in the old Westphalia shaft of the same mine, for every ton of coal raised daily only 54 cubic feet of gas was given off (in one district the volume of methane was 60 cubic feet). In one branch airway only recently opened 824 cubic feet of the gas was produced for every ton of coal raised and 236 cubic feet for every square foot of freshly exposed coal.

Some detailed tests made by the same observers in the area mined from the Kaiserstuhl shaft[a] showed that gas is not only given off freely by the coal as mined, but continues to be evolved in pillar working. The area investigated was 492 feet long by 256 feet wide, making 125,952 square feet of surface, with a coal content of 20,000 tons. The bed was 6½ feet thick and dipped 65 to 70°. This area was divided by a single-track gangway from which diverged seven roadways 6½ feet wide by 6½ feet high, with pillars 33 feet thick.

The pillars are split by rise drifts and worked retreating. The emanation during the period of observation from December, 1885, to August, 1886, was as follows:

Variations in average emanation of methane in original and pillar workings, Kaiserstuhl shaft.

Kind of mining.	Time of sampling.	Volume of methane—		
		Per ton of coal raised.	Per square foot of surface exposed.	Per square foot of freshly exposed coal.
	1885.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
Whole working	December	657	46.9	105.7
	1886.			
	January	880	33.8	110.6
	February	833	25.6	110.3
	March	876	23.9	109.3
Passage from whole to working of pillars	April	1,165	18.0	152.6
	May	1,278	14.7	
Pillar working	June	749		
	July	463		
	August	438		

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[a] Report of Prussian Fire Damp Commission (Translation): Trans. Fed. Inst. Min. Eng., vol. 4, 1893, p. 640; Pellé, M., Rapports de la Commission Prussienne du grisou; Étude des variations de la quantité de grisou dégagée par un quartier d'exploitation: Annales des mines, ser. 8, vol. 9, 1886, pp. 615–617.

From December, 1884, to March, 1885, the production averaged 848 tons of coal per month and the area of fresh-coal surface exposed was 6,200 square feet a month. In April, 1885, the production was 571 tons, exposing 4,350 square feet of fresh-coal surface; in May, 446 tons, exposing 1,750 square feet of fresh surface. In all, 38,400 square feet of fresh-coal surface had been exposed. In the three months of 1885 the production varied from 855 to 1,368 tons per month. The total production from December, 1884, to August, 1885, was 8,838 tons, less than half of the total quantity of coal in the area. These figures show conclusively that although the emanation of gas continued during pillar working, it diminished steadily in volume.

The diminution of gas due to Sunday holidays was very noticeable.

EMANATION FROM A MINE AT LIÉVIN, FRANCE.

Morin[a] presents results of determinations of the volumes of methane liberated in part of a mine at Liévin, France, from 1894 to 1908, showing the relation of volume to the area of fresh surfaces of coal exposed. The results were as follows:

Annual variations in volume of methane in return of part of coal mine at Liévin.[b]

WORKINGS NO. 1.

Year.	Volume of air per minute.[c]	Proportion of methane in air.[c]	Volume of methane per minute.	Area of new surface exposed in year.
	Cubic feet.	*Per cent.*	*Cubic feet.*	*Square yards.*
1894	89,000	0.19	169	289,472
1895	91,532	.27	246	280,026
1896	80,600	.31	250	286,638
1897	89,000	.36	320	284,612
1898	86,680	.45½	395	296,298
1899	87,848	.35½	312	275,886
1900	119,197	.41	489	279,781
1901	135,280	.37½	507	254,378
1902	124,355	.38	472	243,654
1903	190,360	.25	478	323,554
1904	195,665	.20	391	300,033
1905	212,935	.18	382	333,511
1906[d]	179,100	.11½	206	308,256
1907	180,263	.15½	210	344,664
1908	187,600	.15½	292	339,765

WORKINGS NO. 2 AND NO. 5.

1903	88,955	0.07	62	90,669
1904	100,785	.11	111	123,572
1905	130,380	.19	248	189,459
1906	151,180	.16	242	177,981
1907	165,985	.26	432	203,732
1908	174,245	.30	523	245,730

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[a] Morin, Léon, De l'influence des variations de la pression atmosphérique sur les dégagements de grisou, Annales des mines, ser. 10, vol. 16, 1909, pp. 385–437; abstracted in Eng. and Min. Jour., vol. 90, Sept. 17, 1910, p. 565.

[b] Calculated into approximate English measures.

[c] Mean for year.

[d] Forty-nine days' strike.

In the No. 1 workings, which are the oldest in the mine, the gross volume of methane per day steadily increased from 1894 to 1898 to much more than double, whereas the area of fresh surface exposed increased only 2½ per cent. Then with a diminution of fresh surfaces of about 7 per cent the volume of methane decreased nearly 25 per cent. With slight increase of area in 1900 and great decrease in 1901, the methane volume suddenly increased by more than 50 per cent in 1900 and still more in 1901. Then began an irregular methane decline, notwithstanding a general increase of fresh surface. This diminution is explained by Morin by the fact that workings in adjoining beds became so extensive as to drain some of the gas.

In the No. 5 workings, which are more recent than the No. 1, the methane volume steadily increased with extension of the workings, but at a much more rapid rate. These features and many other observations along various lines led Morin to believe that a large proportion of gas entering the return air is from the roof and floor, and that, other things being equal, the amount of gas increases as the workings are extended and the static equilibrium is disturbed. The figures given above do not therefore show the amount of gas given off from a stated area or tonnage of coal because the sampling was not done near the working faces. The column headed "Area of new surface exposed" therefore shows only the activity of mining.

In his report of investigations of relations between gas emanation and barometric change at Liévin, Morin[a] gives some data as to the area of coal surface drained by certain return airways in which the volume of methane was determined. The figures in the following table are calculated from his results, the methane content being taken when it was high at the end of a barometric fall.

Relation of volume of methane to area of coal exposed at Liévin.

Name of return where observation was made.	Methane per 1,000 square feet of coal surface a minute.	Volume of old working.	Name of return where observation was made.	Methane per 1,000 square feet of coal surface a minute.	Volume of old working.
	Cubic feet.	*Cubic yards.*		*Cubic feet.*	*Cubic yards.*
Auguste N	10.0	1,703	Du Souiche, at 200 meters	5.2	30,130
Frederic H	6.4	14,440	Alfred, at 345 meters	2.4	52,400
Du Souiche, at 476 meters	14.7	15,720	Alfred, east	4.0	68,120
Auguste, 31	2.0	19,650	Alfred, at 476 meters	2.3	78,000
Edouard couchant .F	7.5	20,960	East, at 283 meters	4.3	103,490
Frederic, at 200 meters	8.2	21,339	South, at 345 meters	6.4	144,100
Auguste and Du Souiche, 0	5.5	24,628	South, at 282 meters	5.7	262,000

Some additional data on volume of gas in relation to amount of coal mined in the anthracite coal field of Pennsylvania are given on pages 120 and 143, and in the coal field of southern Illinois, on page 224.

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[a] Morin, Léon, De l'influence des variations de la pression atmosphérique sur les dégagements de grisou: Annales des mines, ser. 10, vol. 16, 1909, p. 931. Abstracted in Eng. and Min. Jour., vol. 90, 1910, pp. 565-568.

DAILY VARIATIONS IN METHANE EMANATION.

Several extended investigations have been made to ascertain whether gas emanation is proportionate to the variations in activity in mining from day to day. In 1912 the author also obtained data as to the effect of a cessation in Illinois and Pennsylvania due to a strike, with results given on pages 145 and 219.

WINKLER'S INVESTIGATIONS.

Experiments were made by Winkler[a] to determine the effect of no mining on Sunday. He analyzed air from mines in three districts in Saxony—Chemnitz, Zwickau, and Dresden—selecting mines that were especially gaseous and others that gave off only moderate amounts. The following results were obtained recalculated to English measures:

Comparison between methane emanation on week days and Sundays in coal mines in Saxony.

Mine.	District.	Volume of methane in mine air.		Volume of upcast.	
		Week day.	Sunday.	Week day.	Sunday.
		Cubic feet a minute.	*Cubic feet a minute.*	*Cubic feet a minute.*	*Cubic feet a minute.*
Lugau	Chemnitz	9.2	8.3	540	8,980
Bockwa-Hohndorf	do	25.6	14.2	16,392	12,810
Deutschland	do	9.3	7.0	6,703	6,110
Brueckenberg	Zwickau	24.6	11.1	9,600	8,974
Oberhohndorf	do	4.6	3.7	6,636	6,865
Van Arnim	do	3.8	5.4	20,848	21,412
Zaukeroda	Dresden	2.3	1.1	7,560	6,466
Von Burgks	do	17.4	22.6	13,907	15,455
Hainichen	do	3.9	6.4	9,572	13,314

TESTS OF PRUSSIAN COMMISSION.

The Prussian commission found in the Heinitz mine in one airway when 727 men were at work that the emanation of methane was 70 cubic feet a minute on Tuesday, whereas on the following Sunday, with no mining, the volume of gas diminished to 40 cubic feet a minute.

TESTS BY HILT.

Tests were made by Hilt[b] to ascertain whether the variations in methane during the day were due to barometric change or to mining. For this purpose samples were collected early in the morning before work was resumed, at midday, and at 10 o'clock at night. The results are as follows:

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[a] Winkler, C., Die chemische Untersuchung der bei verschiedenen Steinkohlengruben Sachsens ausziehenden Wetterströme und ihre Ergebnisse, Jahrb. Berg. Hüttenwesen, Sachsen, 1882, pp. 65-84; abstracted in Eng. and Min. Jour., vol. 34, p. 201.

[b] Hilt, C., Bericht über Versuche betreffend den Einfluss des wechselden Luftdruckes auf die Entwickelung des Grubengases, im Auftrage der Preussischen Schlagwetter Commission, Zeitschr. Berg-Hütt. Salinenwesen, vol. 34, 1886, pp. 72-92. Translation by M. Simon, Bull. Soc. l'indus. min., ser. 3, vol. 1, 1887, pp. 595-625.

Variations in volume of methane given off per minute during different times of the day.

Mine.	Point in mine.	Period of observation.	Average methane emanation.		
			Morning.	Noon.	Night.
		1885.	*Cu. meters.*	*Cu. meters.*	*Cu. meters.*
Gemeinschaft	Return 2D	Oct. 5 to 10	184	182	180
Ath-Gouley	Return 1D	Oct. 11 to 17	64	62	60
Gemeinschaft	430 meters in	Oct. 18 to 24	27	31	31
Do	Meister bed	Oct. 25 to 31	29	32½	30

These differences, except in the third set of observations, show no relation to the mining activity, but were found to be closely related to barometric changes.

In the series of methane determinations in the Gemeinschaft and Ath-Gouley mines Hilt [a] gives the following figures, which have been arranged to show the relative amounts of methane given off on the various days of the week for four weeks. They are intended especially to show the effect of the cessation of mining on Sunday:

Methane given off per minute on various days of the week in the Gemeinschaft mine.

RETURN 2D.

Monday.	Tuesday.	Wednesday.	Thursday.	Friday.	Saturday.	Sunday.
Cubic feet.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
144	163	164	....	162	149.5	149
162.5	164	164	183	184	171	139
161	155	171	184.5	191	171	186
171	174.5	179.5	161.5	202.5	191	....
159.5	164	170	176	185	170.5	158

Methane given off per minute on various days of the week in the Ath-Gouley mine.

RETURN ID.

Monday.	Tuesday.	Wednesday.	Thursday.	Friday.	Saturday.	Sunday.
Cubic feet.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
64.5	61	55	55	67	51	51.5
54	48.5	45	57.5	63	60.5	54
56	44	45	64	68	68.5	60.5
66	60.5	58	48.5	60	53	....
60	53.5	51	56	64.5	58	55

In each mine the methane given off increases toward end of week. The workings in Gemeinschaft mine were largely recent, whereas in the Ath-Gouley mine there are extensive areas of old workings. Some of the variations were due to changes in atmospheric pressure.

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[a] Hilt, C., Op. cit., pp. 600–615.

TESTS BY LIVEING.

Liveing[a] made some tests in part of the Boldon mine to ascertain whether cessation of working for a few days caused diminution in gas emanation. The ventilating air varied in volume from 7,900 to 10,435 cubic feet a minute, and the methane from 0.7 to 0.9 per cent. Some of his figures are as follows:

Variations in volume of methane in Boldon mine during mining and after mining had ceased.

Time of taking test.	Methane.	Extent of operations.
	Cubic feet a minute.[a]	
Wednesday, May 14, 12.40 p. m	74.7	Mining full capacity.
2.10 p. m	71.1	Do.
4.10 p. m	74.7	Do.
5.20 p. m	74.2	Do.
Thursday, May 15, 11.00 a. m	72.8	Do.
12.00 noon	74.1	Do.
1.00 p. m	72.7	Do.
2.00 p. m	72.7	Do.
3.00 p. m	79.6	Do.
4.00 p. m	80.9	Do.
5.15 p. m	81.3	Do.
Friday, May 16, 8.00 p. m	72.1	No mining.
9.00 p. m	72.8	Do.
10.00 p. m	72.1	Do.
11.00 p. m	70.0	Do.
12.00 night	67.9	Do.
Saturday, May 17, 1.00 a. m	72.4	Do.
2.00 a. m	65.6	Do.
3.00 a. m	67.2	Do.
4.00 a. m	69.6	Do.
5.00 a. m	66.9	Do.
6.00 a. m	69.3	Do.
7.00 p. m	65.9	Do.
8.00 p. m	68.2	Do.
9.00 p. m	66.5	Do.
Sunday, May 18, 6.30 p. m	67.9	Do.
7.30 p. m	66.6	Do.
8.30 p. m	66.0	Do.

[a] It is probable that the possible plus or minus due to error of anemometer and of methane determination amounts to fully 2 cubic feet a minute.

An experiment was made on two splits of an air current, one draining a face not worked for nearly a year and the other draining fresh workings, both of about the same area. The first gave off 33 cubic feet of methane a minute, and the fresh one 74 cubic feet, showing that in 12 months the diminution was about half, provided the original gas content was uniform in both splits.

PRESSURE OF GAS IN COAL BEDS.

The gas confined in coal beds must exert a pressure closely proportionate to its relative volume, and as the volume is variable the pressure varies accordingly. Observations made with tubes sunk deep in the coal show pressures ranging from several hundred pounds to the square inch to those almost inappreciable. The causes of these variations are difficult to understand. As the gases are believed to be in pores and crevices in the coal, the pressure as mining progresses has a tendency to shatter the coal and throw it out from the face or rib. This condition is common, and in numerous instances men have been killed by masses of coal being suddenly detached. At the Marcinelle-Nord mine, in Belgium, in 1885 about 150 tons of coal was blown out in this way, and numerous large masses were thrown far from the face. Of course at all times the coal in the face, rib, or pillar is under stress from roof pressure and other sources, that has a tendency to break the exposed coal. This pressure is very great in places, especially where the beds dip steeply, some runs of coal being due to roof pressure independent of gas pressure. In such instances also the rapidity with which the gas is given off may be due entirely to the sudden exposure of a large area of coal surface and be no indication of gas pressure.

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[a] Final report of her Majesty's Commissioners appointed to inquire into accidents in mines, 1886, pp. 141-142.

Observations on pressure of the gas in coal have been made by numerous European observers. During the investigation in southern Illinois the author made a number of tests of pressure in the solid coal, with results as given on page 218.

GAS PRESSURE IN COAL BEDS IN ENGLAND

The first extended investigation of this kind was made by Wood [a] in 1880 in English coal mines. The pressures ranged from 28 to 461 pounds to the square inch. They were measured in tubes tightly tamped in holes 3½ to 47 feet deep that had been bored ahead from working faces into the solid coal. The volume of gas was also determined. The collieries were the Hetton, Eppleton, Boldon, and Harton, all old ones, working bituminous coal 3 to 6 feet thick. The workings were 1,228 to 1,268 feet deep.

METHOD OF CONDUCTING TESTS.

A ½-inch pipe was inserted into the hole to within a few feet of its end. At this inner end was screwed a nut holding a washer nearly the diameter of the bore hole (about 2 inches). The outer end was fitted with a collar, and between the collar and the nut were placed, first, a metal socket, and then several soft-rubber washers that could just be forced into the hole. When the nut was screwed up, a fairly tight fit was effected, but the final sealing was made by filling the space around the socket with Portland cement or oakum in cement. In some cases a wooden plug was also forced into the socket. A gage was attached to the end of the tube for reading pressures, which were observed hourly in most cases. In the deeper holes alternations of rubber washers and wooden plugs were used.

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[a] Wood, Lindsay, Experiments showing the pressure of gas in solid coal: Trans. North of England Inst. Min. Eng., vol. 30, 1881, pp. 163–256.

RESULTS OBTAINED.

Some of the results obtained were as follows:

Gas pressures observed in English collieries.

Colliery.	Number of hole.	Depth of hole.	Length of hole.	Greatest pressure.	Time required to develop greatest pressure.	Minimum pressure later.[a]	Time required to develop minimum pressure.[a]
		Feet.	*Feet.*	*Pounds.*	*Hours.*	*Pounds.*	*Days.*
Hetton	1	1,228	9	45	56	....	....
Eppleton	1	1,261	3½	54¾	1	....	....
Do	2	1,261	7½	104½	34	90	3⅔
Do	3	1,261	24½	204	106	152	26
Do	[b] 6	1,261	37	223	174	195	16
Do	7	....	47	235	294	233	18½
Do	8	....	25	221	51	208	8
Boldon	1	1,268	19	425	190	425	3
Do	[c] 3	1,268	32	461	60	....	....
Do	4	1,268	23½	381	25	348	6
Do	5	....	28	176	60	175	18
Harton	1	1,215	16⅛	197	135	197	11
Do	2	1,215	27½	231	126	230	11
Do	3	1,215	37¼	296	84	290	7

[a] End of experiment.
[b] Holes 4 and 5 showed low pressures only 31 and 125 pounds respectively, seemingly due to leakage of gas.
[c] Hole 2, 7½ feet deep, showed pressures up to 299 pounds, but was supposed to have leaked into hole 3.

The eight holes in the Eppleton mine were in working faces of four crosscuts far from the shaft and about 150 feet apart, except two that were closer. The coal was in the Hutton bed, which is about 4½ feet thick, and contained 33.3 per cent of volatile matter other than sulphur and moisture. The five holes at the Boldon mine were close together at the end of some workings nearly a half mile from the shaft, holes 1, 2, and 3 being in the same breast at nearly the same height, and Nos. 4 and 5 being about 40 feet distant. They were in the Bensham bed, which is about 5½ feet thick. Holes 1, 2, and 3 in the Harton mine were also near each other, Nos. 1 and 2 being in the same face and No. 3 about 100 feet away. They were in the Bensham bed, 6 feet thick. The pressure was manifested much more rapidly in some holes than in others. From 2 to 16 days was required before the maximum pressure was reached, when the pressure slowly decreased. In some holes oscillation both in increase and in diminution of pressure followed after the maximum. Careful comparisons with barometric readings showed that there was no relation between variations in atmospheric pressure and those shown by the holes.

The highest pressure was obtained at the Boldon mine, where the gage reached 461 pounds in the deepest hole (32 feet), which is about 84 per cent of the pressure that would be due to a column of water the same height as the thickness of the cover. The Boldon mine had been opened only 11 years, whereas the others were 4 or 5 times as old, and this difference may account for the higher pressure. However, there were great differences in pressure in nearby holes and not always in direct relation to their depths, although some of the results seem to show a fairly close relationship, the ratios of the pressures per square inch being proportional to the square roots of depths.

The direction of hole in relation to cleat seemingly had no effect on the pressures.

The principal features of the more significant test holes are shown in figure 4.

MALLARD'S VIEW OF WOOD'S OBSERVATIONS.

Mallard[a] reviewed the results of Wood's observations and deduced from them some hypotheses as to some of the conditions of gas pressure. He compared the gas to water in a porous stratum and believed the same laws of pressure and movement are applicable to it. He showed that under this condition the gas under high pressure back in the solid coal flows toward the face and to the spaces in the test holes and the outward diminution of pressure can be expressed by a mathematical formula. He explained the great variation in pressure from place to place by variations in original gas content, in porosity of coal, and in conditions that have permitted gas to escape from the bed. With gas confined in the coal under favorable conditions for its retention and a thick mass of strata above, the pressures should be expected to rise to 450 to 600 pounds to the square inch or even higher. In general the highest pressures would be found in coal that presents the lowest coefficient of permeability.

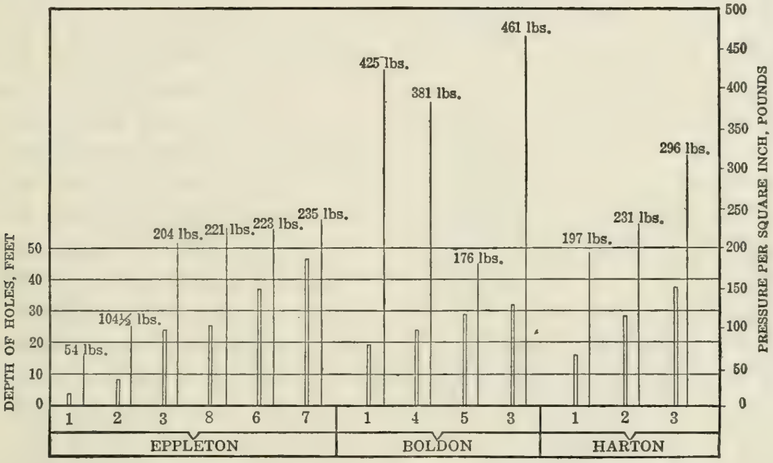

FIGURE 4.—Gas pressures in holes of various depths in English mines. After Wood.

However, the pressure observations by Schorn, Watteyne, and Maquet[b] do not give results in accordance with the formula of Mallard.

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[a] Mallard, E., Expériences sur les pression du grisou dans la houille par M. Lindsay Wood, Annales des mines, ser. 8, vol. 11, 1882, pp. 530–551: Translation, Trans. North of England Min. and Mech. Eng., vol. 33, 1883, pp. 123-132.

[b] Schorn, G., Watteyne, V., and Maquet A., Études sur le grisou: Ann. trav. pub. Belgique, vol. 44, 1886, pp. 365–367.

A dry bore hole in Stafford Main mine, England, showed a gas pressure of 120 pounds, which was manifested in 20 minutes after the gage was set.

GAS PRESSURE IN COAL BEDS IN WALES.

The British commission on accidents in mines had some interesting pressure tests made in South Wales.[a] At the mine of the Harris Navigation Co., the deepest steam-coal workings in South Wales, a 30-foot test hole bored at a depth of 2,133 feet developed a pressure of 150 pounds but found little gas. A second hole bored at a depth of 2,169 feet was 26½ feet deep and showed pressure of 116 pounds. The volume of gas was 0.287 cubic foot an hour. At the Merthyr Vale mine borings 41 feet 2 inches and 49 feet 9 inches at depths of 2,400 and 900 feet showed pressures of 170 and 280 pounds, respectively. At the Celynen mine, near Newport, holes 42 feet, 47 feet 10 inches, and 20 feet 3 inches, at depths of 1,058, 1,480, and 1,500 feet, gave maximum pressures of 129 pounds, 430 pounds, and 318 pounds. The gas volume was at the rate of about 38, 0.4, and 36 cubic feet in 24 hours. A test made in 1886 to show pressure conditions in face of the coal is described in the report of the British commissioners.[b] A 4-inch iron tube was tamped into a bore hole 18 inches deep and fitted with a tight piston. A pressure gage was attached to the side of the tube where it entered the coal. It was expected that when the piston was drawn out a partial vacuum would be indicated, but in most tests the gas was given off so rapidly under the reduced pressure that the gage showed no change. When the piston was pushed in again the gas was forced back into the face but escaped from crevices to a distance of 4 to 5 feet about the hole where, on being lighted, it appeared as numerous small flames.

GAS PRESSURE IN COAL BEDS IN BELGIUM.

INVESTIGATIONS OF SCHORN, WATTEYNE, AND MAQUET.

Schorn, Watteyne, and Maquet[c] in 1885 to 1887 investigated gas pressures in Belgium in an area where the beds are considerably disturbed. One series of tests was made by Watteyne in shaft 7 in the Belle-Vue mine at a depth of 2,264 feet in the Petite Chevalière, a very gaseous bed. The first holes were made in and near the face of a rock tunnel about 9 feet from the steeply dipping coal bed. The holes passed through all of the coal, at this point about 6 feet thick, and iron tubes were set in the holes through the rock and tamped in. The holes were drilled at various angles but were grouped in a few square yards, as shown in figure 5.

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[a] Final report of Her Majesty's commissioners appointed to inquire into accidents in mines, 1886, pp. 21, 147–148.

[b] Final report of Her Majesty's commissioners appointed to inquire into accidents in mines, 1886, p. 21.

[c] Schorn, M. G., Watteyne, V., and Maquet, A., Études sur le grisou: Ann. trav. pub. Belgique, vol. 44, 1886, pp. 351–451.

The pressures are shown in figure 6. A pressure of 555 pounds was obtained in one hole.

In all holes the rise of pressure was very slow at first. After the maximum had been attained in holes 2 and 3 it continued throughout the experiment (10 days), but in No. 1, in which the pressure rose to 330 pounds in 2 days, there was gradual diminution to 150 pounds at the end. In the latter part of the experiment 2 additional holes, Nos. 5 and 6, were bored, and during the boring there was no noticeable diminution of pressure in holes only a few feet distant. The rock tunnel was then driven to the coal, destroying borings Nos. 1, 2, and 3, so that holes 4, 5, 6, 7, and 8, which started obliquely in the floor and roof behind the working face, indicated the pressures (fig. 7). As the coal was uncovered the pressures in these holes diminished gradually, but finally when the coal was completely bared on April 20, they registered 195 and 135 pounds in the two nearest holes (Nos. 5 and 6) and 270 and 412 pounds in those that extended obliquely for some distance to either side (Nos. 4 and 8), the latter not showing any material change from the original pressures. The experiments were repeated when the tunnel approached the Mouton bed 45 feet farther in. Here the pressure went up rapidly the first two days to 525 pounds in one bed and 450 in another and then rose gradually so that at the end of 12 days it was 637 pounds in one hole and 540 pounds in the other.

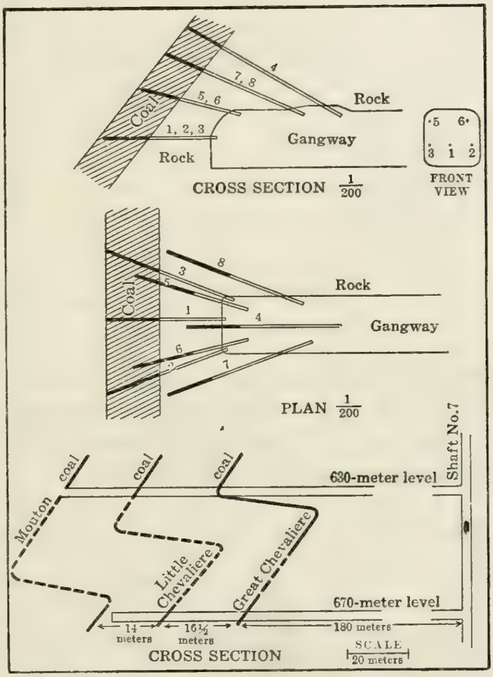

FIGURE 5.—Plan and sections showing location of holes for gas-pressure tests at Belle-Vue mine, Belgium.

The results of these observations show (1) that holes did not affect the pressure at nearby holes, except possibly where there were some open cracks between; (2) that uncovering the coal so as to let out a great volume of gas from a large surface had no immediate effect on holes a few yards away; (3) that even the pressures observed, as high as 637 pounds, do not represent the full pressure of the gas disseminated in the coal if the volume of this gas is four times that of the coal; (4) that the gas is irregularly distributed in coal beds even within short distances; (5) that no law can be applied to this variation in pressure; (6) that the pressure which is established slowly is due to the gas that accumulates little by little in the part of the beds nearest the boring and so establishes an equilibrium against the real pressure of the gas in the bed, the resistance of the compact coal sustaining part of the pressure.

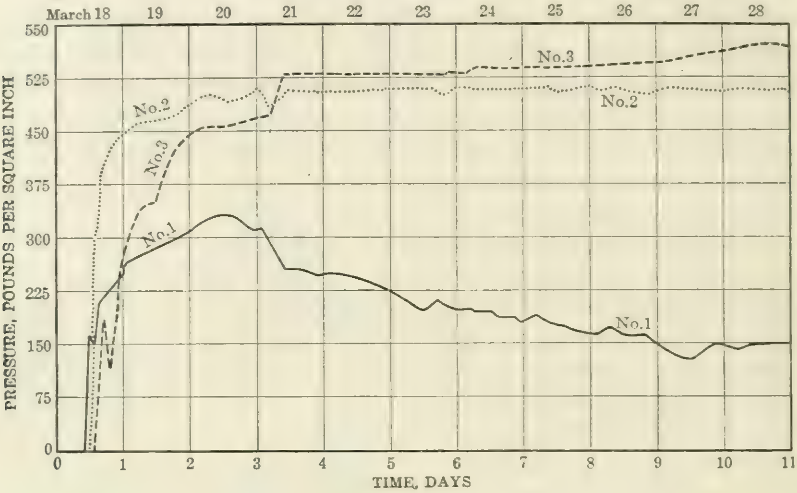

FIGURE 6.—Diagram of pressures in test holes at Belle-Vue mine.

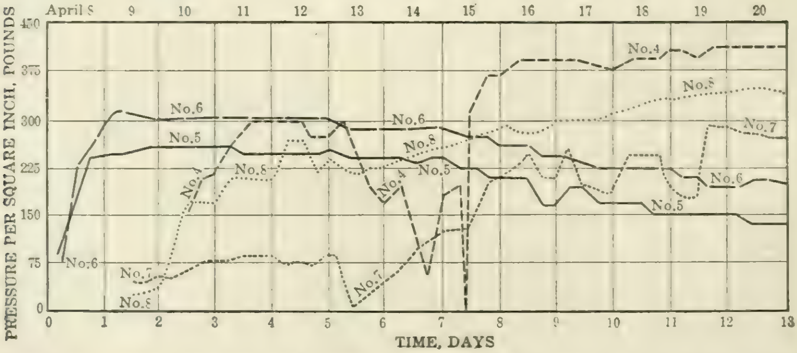

FIGURE 7.—Diagram of pressures in test holes in coal at Belle-Vue mine, Belgium, while the rock tunnel was being continued to the coal.

Ghysen,[a] in presenting an abstract of the results of Schorn, Watteyne, and Maquet, notes that the pressures observed at various places do not indicate the danger of gas outbursts, for in the very dangerous bed "Epuisoire," in the l'Agrappe mine, the pressure was less than 15 pounds, whereas in the only slightly gaseous beds at Grand Hornu a pressure of 60 pounds was found and at Marihaye a pressure of 225 pounds was observed.

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[a] Ghysen, Henri, Quelques considérations sur les dégagements instantanés de grisou: Rev. univ. des mines, ser. 3, vol. 59, 1902, p. 40.

In boring the holes it was noted that those holes showing highest pressure did not give the most gas before being closed, and that most of the gas was liberated in the front part of the hole, possibly because boring cracked the coal in advance and so facilitated the liberation of gas. It was established by these tests that the gas pressure, after attaining a maximum, drops slightly and then remains constant. This may indicate that coal near the hole later absorbs or drains gas from more distant points where there is higher pressure and so establishes an equilibrium. Time is an important factor in the manifestation of the pressure. It was found that when a tube was opened and then reclosed the pressure was attained more rapidly than when the experiment was started. Some fluctuations in the pressure curves appear to indicate waves due to movements of gas through the coal bed.

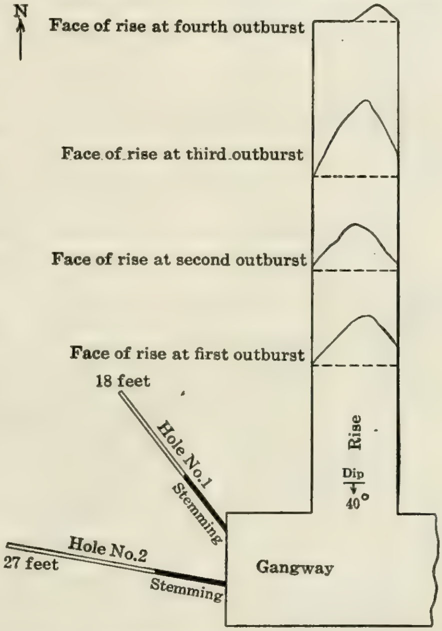
N
Face of rise at fourth outburst
Face of rise at third outburst
Face of rise at second outburst
Face of rise at first outburst
18 feet
Hole No. 1
Stemming
Rise
Dip
40°
Hole No. 2
27 feet
Stemming
Gangway

Figure 8.—Diagram showing position of test holes at Beaulieusart mine and points at which gas outbursts occurred in driving the rise. After Maquet.

TESTS BY MAQUET.

Maquet[a] made tests of gas pressure at the Beaulieusart mine at Fontaine l'Évêque in the Joseph coal bed in September, 1886. The bed dips 40° and, including partings of carbonaceous shale, is about 5 feet thick. Two holes were bored into the bed at a depth of 1,631 feet at the face of a gangway in the mine, one directed to the northwest, designated as No. 1, and the other to the west, designated as No. 2, No. 2 being south of No. 1. They had the relations shown in figure 8.

Iron tubes were tightly tamped into the holes and were provided with pressure gages which were read at intervals for 11 days. The gage on hole 1 soon indicated a pressure of 187 pounds, and after several days 115 pounds was shown on the gage in hole 2. During the experiment the rise or incline was driven rapidly upward from the gangway and in such manner as to cause gas outbursts of moderate volume at points shown in figure 9. The pressure in the two holes was affected in a pronounced but varying manner. The lines of pressure are given in figure 9.

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[a] Maquet, A., Premier note sur les opérations de sondages et de mesures des pressions du grisou dans Beaulieusart en Fontaine-l'Évêque: Ann. trav. pub. Belgique, vol. 44, 1886, pp. 405–445.

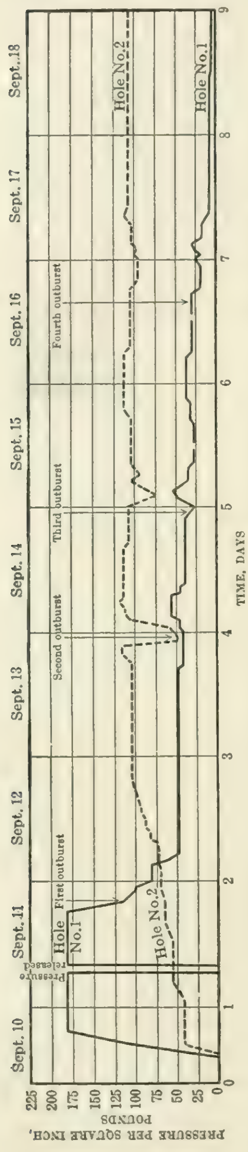

FIGURE 9.—Diagram of pressures in test borings at Beaulieusart mine. After Maquet.

It will be noted in these diagrams that the pressure rose rapidly at first, but became much higher in hole 1 than in hole 2. On the second day the pressure (187 pounds) was released in the tube in hole 1 for several minutes without affecting the pressure in hole 2, which was then gradually rising. This experiment tried at other times caused no oscillation in pressure in either tube, and the original pressure was quickly regained.

In the afternoon of the second day a gas outburst occurred, detaching about 1,700 cubic feet of coal, flooding the neighborhood with gas, and stopping observations for 16 hours. Two hours before this outburst the pressure in hole 1 dropped suddenly and continued to fall for several hours after the outburst, till finally on the next morning (September 12) it reached 50 pounds when it ceased falling. In hole 2, so far as could be observed, the outburst had no effect on the steady rise of the pressure, which finally reached 120 pounds, the last few pounds by a rapid rise.

Soon after this there was a second gas outburst much like the first one. The pressure in hole 2 at that instant suddenly dropped from 120 to 44 pounds. The higher pressure was regained soon after the outburst, as shown in figure 9. Meanwhile the pressure in hole 1 showed a slight fall 3 hours before the outburst, then remained stationary and immediately after the outburst rose again. After a short time it became 12 pounds higher than it had been on the previous day, and then gradually sank and remained stationary at about 34 pounds until near midnight, when it sharply descended to 22 pounds during a third gas outburst in the rise.

This outburst detached about 22,000 cubic feet of coal, but the volume of gas was less than in the previous outbursts. In hole 2 this outburst was preceded three hours by a slight drop in pressure and quickly followed by a sharp descent of about 30 pounds, then a rise to original pressure and another sharp drop of less amount than the first, after which the pressure finally rose to 115 pounds, where it remained into the next day, September 16. Closely similar oscillations were shown in hole 1 after the outburst, the pressures varying from 50 to 28 pounds. Some of these changes were simultaneous and of similar amounts.

On the afternoon of September 16 there was a fourth small outburst of gas. Three hours after this outburst both tubes showed equal falls of pressure and a series of oscillations. After this the pressure in hole 2 rose a trifle and then remained stationary for several days. The pressure in hole 2, however, rapidly diminished after the oscillations to about 10 pounds, and then diminished very gradually for several days.

CONCLUSIONS FROM RESULTS OF PRESSURE TESTS IN BELGIUM.

From the connection of the oscillations of pressure with the gas outbursts Maquet came to the conclusion that a coal bed with its gas-filled pores acts as an elastic body and transmits wave movements due to pressure variations. He suggests that there are centers of pressure of differing degree and intermediate zones of varying pressure in unstable equilibrium, so that the transmission of waves of varying pressure would not be uniform in speed or amount in all directions. These centers of pressure of varying degree would account for the different pressures found in the holes at different points.

Ghysen[a] in discussing the paper does not accept this hypothesis. He holds that the pressure of gas in pores of coal is very high and in stable equilibrium except when cracks give outlet or movement. He explains the rapid drop in pressure in hole 1 as due to a crack opened by mining in the rise and maintains that such cracks started the first outburst. Finally the crack drained off the gas until the pressure dropped to 45 pounds. It did not reach hole 2, but the pressure of the latter was relieved momentarily at the time of the second outburst and following the third and fourth. These breakings of the coal finally led to the declines and ultimate ceasing of pressure in hole 1.

GAS PRESSURE IN COAL IN LIÉVIN MINE, FRANCE.

In 1893 A. Simon,[b] chief engineer of the Liévin mine, tested the pressure of gas in solid coal by experiments much like those of Wood and others. The tubes were inserted far out in the workings, at a depth of about 1,560 feet. The coal contains 30 per cent of volatile matter, and the mine is uniformly gaseous throughout. Two-inch holes were bored into the headings and fitted with copper tubing 0.4 inch in diameter reaching to within 7¾ inches of the bottom. The tamping, damp clay, was of different lengths. Pressures were measured with a gage and volumes of gas with a meter. Two series of holes were tried, one in virgin coal, the other in an area where there may have been some fissuring from mining.

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[a] Ghysen, Henri, Quelques considérations sur les dégagements instantanés de grisou: Rev. univ. des mines, ser. 3, vol. 59, 1902, p. 40.

[b] Simon, A., Notes sur quelques expériences faites au siège No. 1, des mines de Liévin: Annales des mines, ser. 9, vol. 8, 1895, pp. 219-231, abstracted in Col. Guard., Dec. 20, 1895, p. 1164.

TESTS IN FREDERIC BED.

The first series of holes was about 820 feet ahead of the mining in a gangway in the Frederic bed that had been made in the foregoing six months. At that place the bed is about 4¼ feet thick, and the test was near a fault where the strata dip 23°. Six holes were drilled into the side of the gangway to depths of 30¼ to 39⅓ feet with 13 feet or more of tamping. Hole 1 was first; 80 feet farther in was No. 5, and then at intervals of 20 to 25 feet Nos. 2, 4, and 3, the latter being at the end of the gangway. It was found that the pressure was not closely related to length of tamping, but the volume of gas for a given pressure was in proportion to the vacant space at the bottom of the hole. The pressures in holes 2, 3, and 5, all with about 13 feet of tamping, were as follows:

Pressures of gas in Frederic bed, Liévin mine.

Number of hole.	Depth of hole.	Area of surface exposed.	Pressure per square inch.	
			March, 1893.	March, 1895.
	Feet.	*Square feet.*	*Pounds.*	*Pounds.*
2	30¼	10¾	77	59
3	30¼	10¾	59	35
5	39⅓	16⅐	80	52½

The maximum pressure was attained in four to six days in most cases, but sometimes after the cock had been closed the pressure would rise to the maximum in a few hours. The observations show how slowly the coal gives up its gas, or, in other words, its slight permeability. That the roof is only slightly permeable also was proved by a test hole in which a pressure of only 1.4 pounds per square inch was developed.

TESTS IN ALFRED BED.

The other series of tests was in the Alfred bed at about the same depth as the first. The coal is about 7 feet thick, contains 33 per cent volatile matter, and has a hard floor but a friable roof. The holes were made diagonally into a face at the end of an area of active mining. The results were as follows:

Pressures of gas in Alfred bed.

Number of hole.	Depth of hole.	Depth of tamping.	Area of bottom of hole.	Maximum pressure per square inch developed.	Pressure per square inch after 3 months.
	Feet.	*Feet.*	*Feet.*	*Pounds.*	*Pounds.*
1	23	21½	....	64½	49
2	30	27	....	85½	59
3	44	42	1½	96½	59

It is to be noted that the difference in maximum pressure in holes 2 and 3 is small, notwithstanding the great difference in coal surface exposed. This relation is variable. The rapid diminution of pressure in three months was due to the greater permeability of the bed and to some fissuring from the advancing workings. The gas in this series in hole 3 showed higher pressure than in the holes in the Frederic bed and afforded over 0.35 cubic foot a minute, or nearly fifty times as much in relative volume when the small area of coal exposed (1½ square feet) is considered. The maximum pressure observed in the mine was 105 pounds per square inch in a hole 39 feet deep and is very much less than those recorded by L. Wood in his tests in an English mine and by other observers in French and Belgian mines. It was found that the variation in pressure was not uniform, and although it increased with depth of hole in most cases, the results do not accord with Mallard's[a] formula. The long gangway in the Frederic bed where the six test holes were made drained the gas very slowly for about two years, and as shown by the table on page 70, the pressure decreased only about one-third in that time. Mallard's view that the volume of gas increased with pressure was not sustained by Simon's tests, which showed that with practically the same pressures the gas volume per square foot of coal exposed was fifty times as much in the Alfred bed, which is disturbed, as in the Frederic bed, which is undisturbed.

TESTS IN LEONARD BED.

In 1907 Morin[b] made some determinations of pressure of gas in coal in a gangway down the dip in virgin coal of the Leonard bed, where the volume of gas in the return air current was 31 cubic feet per minute. Into this bed bore holes were driven to various depths. A copper tube was inserted into each bore hole to within 8 inches of the bottom. The space about the tube was then carefully tamped with clay to within 4 feet of the bottom.

In one of these holes, which was 25 feet deep, the pressure of the gas was 10.6 pounds per square inch, diminishing to 7 pounds two weeks later. The volume of gas given off at 7 pounds pressure was 23½ cubic feet per minute from an exposed surface of 2¼ square feet. After allowing this gas to flow freely for two hours, the pressure gage was again attached and in 45 minutes the gas regained its original pressure. The pressure remained at this point for three weeks, but a week later it diminished to 4 pounds and still later to less.

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[a] Mallard, E., Expériences sur la pression du grisou dans la houille par M. Lindsey Wood: Annales des mines, ser. 8, vol. 1, 1882, pp. 530–551.

[b] Morin, Léon, op. cit., pp. 385–437.

Compared with the results obtained by Simon in 1893, the pressures are lower, the flow of gas more copious, and the renewal of pressure more rapid. Further tests of the same holes indicated a failing pressure, but without corresponding decrease in volume, which appears to prove that when gas drainage begins the loss is slow at first and then rapidly increases as the drainage becomes well established.

GAS PRESSURES IN COAL AT ST. ÉTIENNE.

In investigating the cause of several coal and gas outbursts at St. Étienne, France, Petit[a] made some tests of pressure of gas in the coal similar to those made by Wood, Schorn, Maquet, Simon, and others. The bed tested was No. 13, which averages about 14 feet thick and is 380 feet below sea level. Petit used iron tubes 0.43 inch in diameter and 3 to 23 feet long, set in holes 2.6 inches in diameter. In order to have a uniform exposure of 3.164 square feet of coal surface in all tests, he placed each tube 6 inches from the bottom of the hole in coal and made the space free from tamping 3 feet 3⅜ inches long. The number of holes tested was 135 and pressures were taken for every meter (3.28 feet).

RESULTS OF TESTS.

In general it was found that the pressure and gas volume increased with depth of holes and with time, but at irregular rates. In the shallow holes up to 10 feet deep the pressures were as low as one-half pound to the square inch, but in some the pressure was as high as 5½ pounds. In holes 23 feet deep the pressure varied from 3 to 18 pounds, but in some of them it was as high as 44 pounds. The time required to give maximum pressures varied. For holes of the same depth the pressure was much less in stalls than in headings.

To test the drainage possibilities of a hole, a boring 15 feet deep with an initial gas pressure of 44 pounds to the square inch was left open for six weeks. The pressure was reduced only to 31.3 pounds, indicating that a hole is not very efficacious in drainage of gas. In one series of tests the holes were bored in the face of a working heading as it progressed into the solid. In one hole of the series a pressure of 17 pounds was observed, although the pressures at previous stages of progress had been less than 1 pound. However, adjoining holes in the same heading gave low pressures, 3 pounds or less, which indicated that the high pressure was due to a crevice leading back into the more solid coal. This interesting experiment was repeated with similar results.

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[a] Petit, M. P., Conférence sur la pression du grisou renfermé dans la 13e couche du Puits du Treuil No. 2, de la Société des Houillères de Saint Étienne: Bull. Soc. de l'indus. min., ser. 3, vol. 8, 1894, pp. 737–770. Abstracted in Col. Guard., vol. 70, Oct. 15, 1895, pp. 733–734.

CONCLUSIONS.

Petit's conclusions were as follows:

1. High pressure is manifested where coal is exceptionally compact.
2. As a rule pressure in coal for the first 3 feet from the face is slight as the gas is draining off rapidly by cracks caused by blasting and the heaving of the strata.
3. Pressure and volume increase with depth, but irregularly, the rate depending on the compactness of the coal.
4. Districts of high pressure are very irregular in extent because the permeability of coal is variable.
5. The time for equal pressures varies, the main factor being permeability until the final equilibrium is established.
6. Holes bored ahead of workings will not greatly decrease pressure nor drain off much gas.

GAS PRESSURE IN COAL IN AUSTRIAN MINES.

The Austrian commission[a] made a number of tests of gas pressure in coal and found in general a rapid increase as the test holes were made deeper and deeper. However, in a 24½-foot hole at Rossitz the pressure was 82 pounds to the square inch, and at Karwin Ostrau a 21½-foot hole gave a pressure of 142½ pounds.

Behrens[b] cites a 13-foot bore hole in a newly opened section of the Hibernia mine in Westphalia in which the gas showed a pressure of 218 pounds to the square inch.

VOLUME OF GAS FROM HOLES IN SOLID COAL.

TESTS AT ST. ÉTIENNE.

Petit[c] made some tests to determine the volumes of gas given off by holes bored into solid coal in connection with his pressure tests at St. Étienne, France. He bored many holes 3 to 23 feet deep and fitted them with iron pipes securely tamped in such position as to leave 3.164 square feet of coal exposed at the bottom of the hole. In general the pressure and volume of gas increased with depth. Although the larger volumes of gas came with the higher pressures, the relation of pressure to volume was by no means uniform. In two holes of the same depth the gas had about 9 pounds pressure in each, but one gave off twice as much gas as the other. In 23-foot holes in stalls, with pressure averaging not quite 1 pound to the square inch, the volume of gas was nearly 0.09 cubic foot per minute; with mean pressures of 3 pounds, it was nearly 0.1 foot; and with pressures of 8 pounds, 0.23 cubic foot. In 23-foot holes in headings with a pressure of 7 pounds to the square inch the volume of gas was 0.06 cubic foot; with a pressure of 9.3 pounds, 0.1 cubic foot; and with high pressures, such as 20 pounds, 0.28 cubic foot per minute.

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[a] Report of Austrian Fire Damp Commission: Abstracted by Annales des mines, ser. 9, vol. 1, 1892, pp. 243–244; Trans. Fed. Inst. Min. Eng., vol. 3, 1891–1892, p. 533.

[b] Behrens, —, Beiträge zur Schlagwetterfrage: Oest. Zeitschr. f. Berg- Hüttenwesen, vol. 45, 1897, pp. 43–46, 63–67, 74–79.

[c] Petit, M. P., Conférence sur la pression du grisou renfermé dans la 13^e couche du Puits de Treuil No. 2 de la Société des Houillères de St. Étienne: Bull. Soc. l'indus min, ser. 3, vol. 8, 1894, pp. 737–770; abstracted in Col. Guard., vol. 70, Oct 18, 1895, pp. 733–734.

TESTS AT LIÉVIN.

In Simon's[a] determination of pressures in solid coal at Liévin, France, measurements were made of the volume of gas given off in holes 30 to 39 feet deep. One hole containing about 13 feet of tamping and an exposed coal area of about 16 square feet, gave off 7½ cubic feet of gas in the first 20 seconds. The volume decreased to about one-third of a cubic foot an hour. Three days later, when the pressure was 42 pounds, gas was given off at a rate of 4½ cubic feet in the first 20 seconds after the cock had been opened, and then the average volume decreased to about one-fifth of a cubic foot an hour, a moderate amount. The volume of gas from a given pressure was in proportion to the vacant space at the bottom of the hole. In tests in another bed of coal (Alfred) one hole with only 1½ square feet of coal exposed at the bottom gave off 0.35 cubic foot of gas a minute, a relative volume fifty times greater than given by the hole in the previous test, the area of coal exposed being considered.

TESTS BY WOOD IN ENGLISH MINES.

Wood,[b] in conducting his determinations of gas pressures in the solid coal, measured the volumes of gas given off by some of the holes. Each pipe was set so as to leave a tubular chamber at the end of the hole. Unfortunately the chambers varied in size from 1¼ to 3 inches in diameter and from 2 to 6 feet in length, so that the coal surface exposed varied from 95 to 570 square inches. The gas emanations varied from 0.6 to 15.72 cubic feet an hour, or from 0.3 to nearly 6 cubic feet to each square foot of coal exposed. The results were as follows:

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[a] Simon, A., Notes sur quelques expériences faites au siège No. 1 de mines de Liévin: Annales des mines ser. 9, vol. 8, 1895, pp. 219–231. Abstracted in Col. Guard., Dec. 20, 1895, p. 1164.

[b] Wood, L., Experiments showing the pressure of gas in solid coal: Trans. North of England Inst. Min. Eng., vol. 30, 1880–81, pp. 163–256.

Quantities of gas from test holes in solid coal.

Colliery.	No. of hole.	Depth of hole.	Area of coal surface exposed.	Maximum volume of gas per hour.		Maximum pressure.	Colliery.	No. of hole.	Depth of hole.	Area of coal surface exposed.	Maximum volume of gas per hour.		Maximum pressure.
		Feet.	*Sq.ft.*	*Cu.ft.*	*Cu.ft. per sq. ft.*	*Lbs.*			*Feet.*	*Sq.ft.*	*Cu.ft.*	*Cu.ft. per sq. ft.*	*Lbs.*
Eppleton.	1	24½	2.65	15.7	6.0	204	Boldon...	4	23¼	2.60	2.6	1.0	381
Do....	2	37	3.96	4.3	1.1	223	Do....	5	28	2.65	10.3	3.9	179
Do....	3	47	3.96	6.1	1.5	235	Harton...	1	16	2.40	1.1	.4	197
Boldon...	1	19	4.24	1.2	.3	425	Do....	2	27½	2.80	2.3	.8	231
Do....	2	7⅔	1.23	.6	.5	298	Do....	3	37¼	3.52	5.0	1.4	295
Do....	3	32	2.80	.7	.3	461							

In most cases the minimum amount of gas given off, so far as observed, was about half as much as the maximum. In the Boldon holes the maximum volume was not attained until the measurements had continued for some time, whereas in the others it was quickly attained. The maximum pressure was developed prior to the time of maximum gas emanation. Barometric observations made throughout showed no relation of barometric pressure either to volume or pressure of gas. In No. 3 hole at Eppleton volume observations were made for three weeks, the volume determined varying from 11.40 cubic feet per hour at the outset to 6.86 cubic feet at the end of the test.

EFFECT OF ROCK AND WATER PRESSURE ON GAS PRESSURE IN COAL.

The gas in coal bears the pressure of the overlying strata, so far as that pressure tends to compress the pores holding the gas. Another important factor that has been mentioned is the pressure of water in the overlying strata. It is a well-established fact that all rocks of the upper few thousand feet of the earth's crust contain more or less water in their pores and this ordinarily constitutes a water column extending up to the ground-water level of the district. There are no "impermeable" rocks, although the texture of glassy lavas and of some compact crystalline rocks is so fine as greatly to impede water movement except where the rocks are fissured. Clays and shales permit little water movement, but underground their pores are usually saturated with water. So-called "bone-dry" bore holes and mine workings yield materials that contain considerable interstitial moisture when tested in the laboratory.

The coal measures consist largely of alternations of sandstone and clays or shales containing considerable water that is much in evidence in some mines, and coal itself contains from 1 to 10 per cent of water (air-drying loss). This water, when it fills the pores and crevices of the coal and extends to the surface, constitutes a column which in a mine 1,000 feet deep has a pressure of 435 pounds to the square inch. This pressure is not manifested directly in a mine, for it is largely sustained by friction, capillarity, or slowness of delivery from the less permeable beds. Although the water may not be sufficiently mobile to penetrate into all the pores in coal containing gas, its pressure must bear on many of them. In a mine, part of the water pressure is relieved by the flow of water from various outlets, but the pressure is often manifested to the amount of many pounds to the square inch when a large water-bearing fissure is encountered. Draining the strata by pumping and mining diminishes the water pressure, but the practical effect of such relief as a factor in gas emanation has not been ascertained.

Rock pressure in mines increases directly with the depth, and averages about 1 pound to the square inch for each foot of depth. Therefore coal at a depth of 1,000 feet is under pressure of a half ton to the square inch. The bearing of this factor on gas in the pores of the coal has not been fully considered, but when the coal is removed and released from such a great compressive strain it expands materially and there is readjustment of stress from the interior to the surface of each lump of coal, as well as of the face, of the pillars, and of the roof and floor.

PERMEABILITY OF ROCKS AND COAL TO GAS.

The gas in the coal, especially where the strata are uplifted and flexed, is only a remnant of the original amount, for leakage has been in progress for thousands of centuries. That gas will penetrate rock for long distances has been well established, and although sheets of fine-grained materials must greatly impede its circulation, yet time is by far the most important factor. Many cases are known of gas wells securely plugged from which the gas has flowed laterally into other wells or into mines. The rate at which gas escapes to the surface in any coal field is as a rule very slow and the escape is so general that it is not apparent, except in places along faults or joint plains where at some localities it manifests itself most vigorously.

ESCAPE OF GAS FROM STRATA NEAR WILKES-BARRE, PA.

Not long ago a large amount of coal gas was bubbling up through the water of the Susquehanna River and the sloughs opposite Wilkes-Barre, Pa., and it was frequently ignited. At one place a pipe forced some distance into the sand where bubbling occurred supplied gas enough to light and heat a house near Market Street bridge.

Several years ago a vigorous "blower" was uncovered in the deep cut of the Nanticoke Branch of the Central Railroad of New Jersey a mile east of Nanticoke, Pa., which as yet shows little diminution of force. There are in various parts of the field many small gas outlets that illustrate how general is the escape of gas.

The proportion of gas that has escaped from coal beds can not be determined, but it varies greatly, and in places the gas is practically all gone. This is the case along the outcrop zones, and in shallow basins where the cover is thin or consists of coarse-grained rocks. As shown in previous pages probably all coal contains some methane, but the word "gaseous" is only applied when there is a sufficient emanation to show in a safety lamp.

ESCAPE OF AIR FROM SEALED CHAMBER IN MARYLAND MINE.

An interesting observation in this connection was made some years ago by Randolph[a] in a mine in the Georges Creek district, Md., working the Pittsburgh bed, which is there soft and friable and intersected by numerous slips. During the installation of a new pumping system the water was allowed to flood the lower workings and as some of these chambers rose from the main gangway and had no outlets, a large body of air was entrapped in them under a water head of about 40 feet part of the time. At the end of 18 months, when the water was pumped out, it was found that the chambers had been filled with water to the roof and consequently all the air had been forced out through the nearest outlet which was 200 feet away through the coal bed. When the mine was unwatered below the level of the chambers some of the air worked back again and finally presented a partial vacuum equal to that produced by a water column 7 feet high.

Randolph also cites an instance of the impenetrability of the "slate" above the coal in this mine. A heading passing over a dome was partly filled with water that imprisoned considerable air. When the mine was pumped out it was found that the water level had never reached the roof, although at one time the air had supported a head of upward of 80 feet of water. In order to escape the air had to pass through the "slate" at right angles to the stratification, but could not do so to any perceptible degree.

The slowness of movement of gas through the coal has been demonstrated by some of the pressure tests described on page 60, which were so conducted as to throw light on this condition. However, the demonstration applied mostly to solid coal and the time covered by the experiments was short.

Simon found evidence of the passage of gas into the overlying strata at Liévin, France.

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[a] Randolph, B. S., Notes on unwatering a flooded mine and on permeability of natural strata to air: Trans. Am. Inst. Min. Eng., vol. 24, 1894, pp. 21-25.

GAS IN STRATA ADJOINING THE COAL.

Shales and sandstones above or below the coal bed or interlaminated with it contain more or less gas which is liberated as mining progresses.

Morin,[a] who investigated the gas conditions at Liévin, believes that such beds are an important source of gas in mines and the results of some of his tests appear to substantiate the idea. It is found that generally the amount of gas in a mine increases as the mining area is extended, even if the area of working faces does not increase. This increase is due in large part to increased area of coal exposed in rib, pillar, and gob, but Morin believes that these soon lose their gas and the increment comes from the floor and roof. As coal is removed and for a while afterwards the overlying and underlying rocks move more or less and thus many fissures are formed from which gas escapes either from the rock itself or from adjoining coal or coaly beds. Naturally this emission of gas is more rapid near the working faces when there is more gas and fissuring is most active. Bore holes drilled into the floor and roof of the coal at Liévin showed little gas at a distance back from the face, although there might be considerable of it above and below the solid coal.

Simon[b] tamped 20-foot tubes in the roof of the Frederic coal bed at the Liévin mine and found a pressure of only 1.4 pounds per square inch, though the pressure in the coal below was from 62 to 80 pounds. In the newly opened Alfred bed the returns at working faces contained 0.4 per cent of methane, whereas at the extremity of the same return the amount was nearly 0.9 per cent and under similar conditions 0.5 to 0.9 per cent has been found in the Arago bed.

A further example is given in an airway passing above the Du Souich bed. It showed no gas even when the ventilation was not effective, but when two working chambers in the coal below were extended under this airway gas became perceptible which undoubtedly worked up through fractures in the strata, due to the removal of coal.

Morin also made tests of the amount and the pressure of gas in rocks. One test was in an overturned part of the Alfred bed, where a 5-foot hole in the wall gave a pressure equal to 0.4 inch of water (about one-seventieth of a pound to the square inch). A second hole in a gangway 2 years old yielded gas containing 6.3 to 5.7 per cent of methane, the volume being one-eighth to one-fifth of a cubic inch a minute. Similar tests in the Du Souich workings at different places gave varying results. One hole 5 feet deep in the wall of some workings 3 years old gave off air and gas containing 2.2 per cent of methane, but no pressure was evident; another hole in the roof at another point in workings a year old gave off gas containing only 0.39 per cent methane, but doubtless this hole had crossed a fissure; and a third hole in the roof gave off a small flow of gas containing 5 and 4.6 per cent of methane. These tests all prove that methane lingers in adjoining strata after the coal has been removed. Some tests were made in undeveloped sections, one being 65 feet above the Arago bed. A hole 6 feet deep yielded samples of gas containing only 0.39 and 0.065 per cent of methane. Another hole 5 feet deep in an unworked region yielded air containing 0.19 per cent methane, whereas a third hole 4 feet deep, 13 feet above the Beaumont bed, yielded gas with a methane content of 3 per cent. These results show that at a distance from the coal the amount of methane in the strata is very small, but near the coal the amount is considerable.

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[a] Morin, Léon, De l'influence des variations de la pression atmosphérique sur les dégagements de grisou: Annales des mines, ser. 10, vol. 16, 1909, pp. 385-437. Abstracted in Eng. and Min. Jour., vol. 90, Sept. 17, 1910, pp. 565-568.

[b] Simon, A. Notes sur quelques expériences faites au siège No. 1 de mines de Liévin: Annales des mines, ser. 9, vol. 8, 1895, pp. 226-227.

In one shaft in Prussia gas began with clay "slate" at 13 feet below ground and extended to the top of the Wealden sandstone 551 feet below. The gas outflow was very strong at 515 feet in dark bituminous clay "slate." In sinking the shaft (No. 3) for the Woodward mine just north of Wilkes-Barre, Pa., gas was found in the sandstones and other rocks in large quantity and gave trouble all the way down. At one stage of progress the outflow was estimated at 1,000 cubic feet a minute. Possibly the gas was rising from the underlying coal beds, but some of the rocks were shales, relatively impervious.

A boring in the Schaumburg district was in shales; at a depth of 695 feet, or 280 feet above the coal bed, gas was encountered which threw a 2-foot column of water for one and one-half hours and was in vigorous action at times for two and one-half months.

GAS IN A SANDSTONE STRATUM IN PENNSYLVANIA.

A rock tunnel in the "Harry E" anthracite mine near Wilkes-Barre, Pa., penetrated a sandstone that gave off considerable methane. A sample of the fresh rock was sealed and sent to R. T. Chamberlin for a determination of its contained gases. The sample was broken into fragments the size of small marbles, which were then placed in a vacuum bottle and the air exhausted. Of course, considerable gas was lost in this process. At the end of 21 days the gas that had accumulated in the vacuum bottle during this time was pumped out and analyzed. The volume of gas at 32° F. and 30 inches pressure, amounted to only 0.013 per cent of the volume of the rock used. The composition of the gas was as follows:

Composition of gas from sandstone layer.

[Analyst, R. T. Chamberlin.]

	Per cent.
Methane	4. 2
Carbon dioxide	1. 9
Air	70
Nitrogen (excess over air)	23. 9
	100

It is probable that the methane in this rock came from the coal below and was stored in the pores of the sandstone. Doubtless most of it passed out of the rock rapidly, as the excavation progressed.

RELATION OF VOLUME OF GAS TO UNDERGROUND TEMPERATURE.

Very few tests have been made to determine the relation of gas emanation to underground temperature. At all places temperature increases with depth, but the rate of increase is variable. Higher temperatures naturally cause gas to escape from the coal more rapidly, but whether it is sufficient to be of any practical moment has not been determined.

COAL OXIDATION AS A SOURCE OF GAS.

A possible factor in the mine-gas problem is the abstraction of oxygen from the air by coal. This process appears to progress in all kinds of coal, but at very different rates, some coals showing slight disposition to absorb oxygen, whereas others absorb a large amount.

INCREASE IN TEMPERATURE FROM OXIDATION.

The result of oxidation is the production of carbon dioxide, accompanied by an increase of temperature which accelerates the emission of the methane held in the coal. Haldane and Meachem [a] investigated this matter and found that the resulting increase of temperature was notable. At the Hamstead colliery in South Staffordshire at the bottom of the shaft, which is 1,880 feet deep, the average air temperature was about 11° higher than at the surface and rose 6° F. for every 3,000 feet along the main intake, rising to 80° or 85° F. in the workings. The temperature of the return air diminished from the face to the upcast, but at a slower rate than the increase in the intake air. In one split the temperature of the intake air was 60° F., of the rock in the mine due to depth, 68° F.; and of the upcast air, 77° F. The ventilating air lost in oxygen 3.13 times more than it gained in carbon dioxide in this mine, but in other mines the ratio was only about 1.6.

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[a] Haldane, John, and Meachem, F. G., Relation of underground temperature and spontaneous fires in the coal to oxidation: Trans. Inst. Min. Eng.; vol. 16, 1899, pp. 457-492.

Haldane and Meachem concluded that the increase of temperature was mostly due to oxidation of coal, and that in general "the temperature increment of the mine air rose with the diminution of oxygen." They also suggest that carbon dioxide in various kinds of mines and pits may be largely due to oxidation. A self-recording maximum thermometer placed in a 10-foot hole in the gangway rib soon recorded 66° F., but four years later the temperature had risen to 90° F. This and other observations show the gradual penetration of oxidation and the resulting rise of temperature in the coal exposed.

ABSORPTION OF OXYGEN BY COAL SAMPLES.

Porter and Ovitz[a] found that oxygen is absorbed rapidly and for a long period by fresh coal and but little carbon dioxide results. An excellent illustration was a test with 22 pounds of Connellsville coal. In one day after mining it absorbed nearly 60 cubic inches, or half of the oxygen in 610 cubic inches of air, and gave off little more than one-tenth as much carbon dioxide as would have been formed if all the oxygen absorbed had combined with carbon and been evolved as carbon dioxide. They suggest that the reaction is probably a direct combination of the oxygen with certain fixed components of the coal, as it has been shown by Boudouard[b] and others that certain compounds in coal are unsaturated with oxygen and its absorption produces humic acid or related substances.

The rapidity of absorption was shown by tests with lignite from Sheridan, Wyo., and bituminous coal from Benton, Ill., which in less than 15 days had exhausted oxygen from a volume of air equal to their own volume, but neither coal gave off more carbon dioxide than one-tenth of the volume of oxygen absorbed. That this oxygen is probably taken into chemical combination rather than mechanical absorption is shown by a test of Benton coal. A sample of this coal, that had been supplied with oxygen for five months, absorbed nearly seven times as much oxygen as it originally contained. The sample was heated to 212° F. for 15 minutes. The gases evolved contained no excess of oxygen over that in air.

EFFECTS OF VARIATION OF ATMOSPHERIC PRESSURE ON GAS EMANATION.

It is a very old and deeply seated idea that there is a close connection between the weather and the amount of fire damp in mines, and even before the barometer was invented coal miners regarded increased gas emission as an indication of the close approach of stormy weather. The idea has been prevalent also that explosions are most frequent at times of low atmospheric pressure or storms. Sir Frederick Abel has shown this opinion to be largely erroneous. He gave a list of explosions during the years 1875 to 1885, involving the loss of 2,229 lives, and by reference to weather records showed that only 17.4 per cent of the mortality was at a time when the barometric pressure was below the average and that half of the explosions occurred when the pressure was increasing. If the frequent small accidents due to various causes be excluded, three out of four of the explosions were at times of high pressure or anticyclonic conditions. We now know, furthermore, that many of these explosions were caused by dust ignited by some accidental explosion and may have had no relation to increase of gas in the mine.

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[a] Porter, H. C., and Ovitz, F. K., The escape of gas from coal: Technical Paper 2, Bureau of Mines, 1911, pp. 10-12.

[b] Boudouard, O., Études sur les charbons: Bull. Soc. chim. de France, ser. 4, vol. 5, 1909, pp. 365-381.

It is generally conceded that diminution of atmospheric pressure affects the liberation of gas from coal, especially from old workings and crevices where the gas has accumulated. This relation, the effects of which have been repeatedly noticed by miners, has been fully substantiated by elaborate scientific investigations. In places where most of the escaping gas has been under notable pressure in the coal the volume emitted can not be materially affected by a change of atmospheric pressure. Various observers have shown that as gas approaches a face of coal its pressure gradually diminishes and in the outer few inches becomes very low. A ''fall of barometer'' of 1 inch indicates a diminution of atmospheric pressure of nearly one-half pound per square inch. Such a change taking place in a few hours must decidedly affect the equilibrium of the atmosphere in the mine. The chief result is an expansion of the air, a decrease of one-half pound in pressure causing an expansion in volume of about one-thirtieth, or 3⅓ per cent. As the expansion is gradual, the results can have no direct effect on the strong air currents of the main ventilation, but the still air in the old workings and in crevices would be affected by it and some gas held in the coal at the pressure of the atmosphere before the change would be given off when the pressure was relieved. An air current traveling 500 feet a minute, a not unusual rate in some gaseous mines, has a pressure of only about 1 ounce to the square inch, equivalent to about 0.14 inch of barometric change.

The volume of gas that may be forced out of old workings with changes of atmospheric pressure may be more clearly understood if considered on a quantitative basis. Assume that an area of old workings 100 acres in extent and 10 feet high is filled with still air carrying 2 per cent methane and having outlet to an air current of 20,000 cubic feet a minute. If there were 50 per cent of open space the volume of methane in these workings would be 440,000 cubic feet. As a barometric fall of 1 inch causes an expansion of about 3 per cent in a given volume of air, a decrease of atmospheric pressure of 0.1 inch would expand this still air 0.3 per cent and drive 1,320 cubic feet of methane into the airway. If one hour were required for the barometric change and reestablishment of atmospheric equilibrium, the rate of discharge would be about 22 feet a minute, which would add to the gas in the airway only 0.11 per cent of methane. However, the change might disturb the general equilibrium and start the flow of the entire body of still air in the old workings into the return. In the 20 hours or more that would be required to drain the 100 acres at the rate of 20,000 cubic feet a minute, the methane increment in the air current would be 1.8 per cent, which would of course be a most decided change, whatever the normal methane content of the return air.

In many mines there are vast areas of old workings in part not well ventilated, and the air in these contains more or less methane. The Prussian Fire Damp Commission [a] found that in the Ath-Gouley mine (Wurm coal field) the spaces amounted to 9,110,000 cubic feet, and 7,410,000 in part of the Gemeinschaft mine. In one English mine it is estimated that the open space in old workings amounts to 36,000,000 cubic feet.

In the following paragraphs are given the results of some of the many investigations of the relation between atmospheric changes and variations in methane in mines.

INVESTIGATIONS IN BRITISH MINES.

Galloway's [b] observations in Scotland did much to establish the belief that there was an important relation between barometric change and the volume of gas given off by mines, and although his investigation was not extensive it led to the passage of the Mines Regulation Act in 1872, which required barometric observations at all collieries. Experiments in German mines by Schöndorff [c] and Nasse [d] in 1875 to 1877 showed that the methane content in the returns was greatly increased in periods of low pressure, especially in those mines where there were extensive areas of old workings with poor ventilation.

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[a] Report of Prussian Fire Damp Commission (translation): Trans. Fed. Inst. Min. Eng., vol. 4, 1893, p. 643.

[b] Scott, R. H., and Galloway, William, On the connection between explosions in collieries and weather: Proc. Roy. Soc., vol. 20, 1872, pp. 292–305.

[c] Schöndorff, A., Untersuchung der ausziehenden Wetterströme in den Steinkohlen-Bergwerken des Saarbrückens: Zeitschr. Berg.- Hütt.-Salinenwesen, 1876, p. 114.

[d] Nasse, V. H., Beobachtungen über die Beziehungen des Auftretens schlagender Wetter in Steinkohlengruben zu den Veränderungen des Luftdruckes: Zeitschr. Berg.- Hutt.-Salinenwesen, vol. 25, 1877, pp. 267–280.

The inquiry into the ventilation of coal mines in England in 1908 by Cadman and Whalley [a] of the Royal Commission of Mines resulted in finding that in many mines a diminution of atmospheric pressure was reputed to have caused more mine gas to appear in the workings, but no precise determinations were made. Redmayne,[b] chief inspector of mines of Great Britain, states that sudden diminution of atmospheric pressure causes large amounts of gas to come out of old workings, and also increases the discharge of blowers. Wabner [c] discusses the influence of atmospheric pressure and gives various data showing its importance.

INVESTIGATIONS IN PRUSSIAN MINES.

TESTS BY HILT NEAR AIX-LA-CHAPELLE AND KARWIN.

The Prussian commission investigated the effect of atmospheric influence on methane emanation at the Ath-Gouley and Gemeinschaft mines near Aix-la-Chapelle and at the Gabriele mine near Karwin, in Austrian Silesia. At all three places a close relation was found, so that the results were confirmatory.

The investigations at the Ath-Gouley and Gemeinschaft mines were conducted in September and October, 1885, by Hilt.[d] Both mines work the Grosslangenberg bed, which is very gaseous. The Ath-Gouley mine contains large areas of old workings, but the Gemeinschaft mine was in fresh dip workings which gave off much gas. In each mine a split of the return air was sampled every morning at 5 o'clock, and the volumes of methane and carbon dioxide were determined. One week the samples were taken four times a day, and for another week samples were taken in two different parts of the Gemeinschaft mine where the workings were particularly fresh. Air from workings in another bed, "Meister," was included in this last series. These latter samples were taken to determine whether the variations in mining from day to day and during parts of the day would account for the changes of methane content in the return, but the relation was not established. Some of the results of the tests in September, 1885, are given in figure 10.

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[a] Cadman, John, and Walley, E. R., Report of an inquiry into ventilation of coal mines and methods of examining for fire damp, 1909.

[b] Redmayne, R. A. S., Ventilation of mines, London, 1911.

[c] Wabner, Robert, Ventilation in mines, 1903.

[d] Hilt, C., Bericht über Versuche betreffend den Einfluss des wechselnden Luftdruckes auf die Entwickelung des Grubengasses. Im Auftrage der Preussischen Schlagwetter Commission. Zeitschr. Berg-Hütt.-Salinenwesen, vol. 34, 1886, pp. 72–90. Translated and reviewed by M. Simon, Bull. Soc. l'indus. min., ser. 3, vol. 1, 1887, pp. 595–625; by M. de Vaux, Rev. univ. des mines, vol. 19, 1887, pp. 395–419; and by L. L. Belinfaut, Trans. Fed. Inst. Min. Eng., vol. 4, 1893, pp. 645–646.

Hilt thought that the experiments proved absolutely that variations in atmospheric pressure affected the emission of gas in both mines. The barometric variations were small at the time of the tests, but their effect was plainly discernible in corresponding variations in methane content, especially in the returns of the Ath-Gouley mine. A rise in barometer was followed by diminution of the volume of methane and carbon dioxide, and a fall in barometer by an increase in the volume of methane, and always within 24 hours. The more rapid the rise or fall the greater was the variation in the percentage of gas. Moreover, the outflow of methane showed a tendency toward equilibrium, for when, by reason of a considerable fall in barometric pressure, the flow had risen much above the mean, it appeared to have a tendency to decrease. The absolute pressure was found to be of less importance than the relative changes, especially when the changes were rapid. In tests made at the Ath-Gouley pits, October 11 to 17, in a region of old workings having open spaces aggregating 9,110,000 cubic feet, comparatively slight variation of atmospheric pressure caused variations of 70 per cent in the mean volume of gas in the returns, and these variations appeared to be independent of the amount of coal being mined. The opinion was stated that at this mine a great decrease of atmospheric pressure might double the volume of methane. In the long-wall and dip workings of the Gemeinschaft mine, where most of the gas was from solid coal, the effect of changes of atmospheric pressure was much less marked and it was somewhat modified by the variations in the mining operations. One

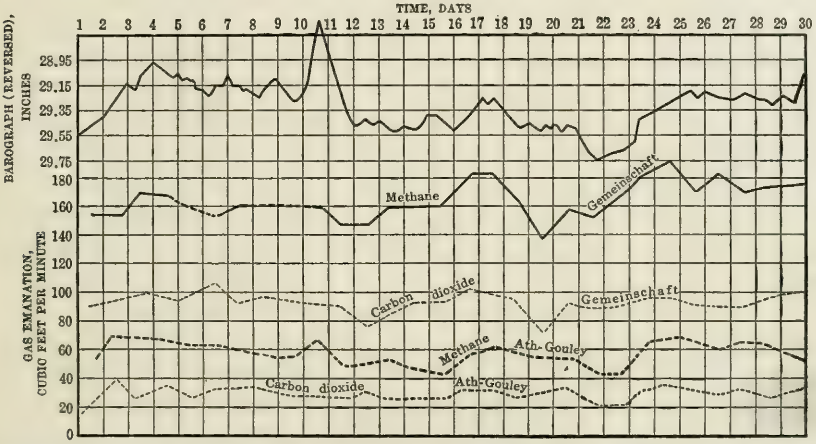

FIGURE 10.—Curves showing variations in volume of methane and carbon dioxide in relation to variations in atmospheric pressure, Gemeinschaft and Ath-Gouley mines, Prussia, September, 1885. After Hilt.

notable irregularity in this mine was a great increase of methane on October 21 and 22, with only a slight fall of barometer, and as there were no old workings this increased flow must have come from the face. Doubtless some crevices were opened or a body of coal entered which contained an increased volume of gas.

REVIEW OF HILT'S WORK BY MALLARD AND LE CHATELIER.

Mallard and Le Chatelier [a] reviewed Hilt's report in great detail, and, although they agreed that some relation was proven, they claimed that it was in returns receiving air from extensive areas of poorly ventilated old workings. They thought, however, that the tests in the new workings appeared not to show any relation, for there was more discordance than accordance in the relations in the fresher workings at Gemeinschaft and not very close relation in the workings in the Meister bed, notably in one of the most rapid falls of barometer. They point out that this is to be expected in fresh workings where the gas is given off under pressure. Mayer,[b] who made extensive researches on gas evolution in mines in Polnisch-Ostrau, concurs in the idea of increased emanation of methane caused by diminished atmospheric pressure, but believes that old workings are principally affected and in no case is the increase likely to be dangerous in a well-ventilated mine.

INVESTIGATIONS IN AUSTRIAN MINES.

TESTS BY KOEHLER AT KARWIN, AACHEN, AND HIBERNIA.

A series of tests extending over a period of six months was made in 1885 by Koehler [c] in the Gabrielle mine at Karwin, in Westphalia. The mine is a very gaseous one, with an average of about 2½ per cent of methane in the main return, equal to about 800 cubic feet a minute. Five-gallon samples of this air were taken daily and also samples of the air in a return from districts entirely in fresh workings in the Karl bed. By plotting percentages of methane under a curve of atmospheric pressures based on readings at the top and the foot of the shaft, he obtained the results given in figure 11. He found that the proportion of methane increased with barometric fall and that the more abrupt the fall the greater was the rate of increase.

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[a] Mallard and Le Chatelier, Sur les travaux de la Commission Prussienne du grisou: Annales des mines, ser. 8, vol. 9, 1886, pp. 638–664.

[b] Mayer, Joh., Über den Einfluss der Luftdruckschwankungen auf die Entwickelung von Schlagwettern bei besonderer Betrachtung der auf Gabrielen-Zeche in Karwin ausgeführten Versuche: Oest. Zeitschr. Berg- Hüttenwesen, vol. 34, 1886, pp. 35–38, 53–61, 69–72.

[c] Koehler, G., De l'influence des variations de la pression atmosphérique sur les dégagements de grisou. Rapport sur les expériences faites dans les mines de Karwin (Silésie autrichienne). Translated by Grey, M. R., Bull. Soc. l'indus. min., ser. 3, vol. 1, 1887, pp. 595–625; and Rev. univ. des mines, vol. 19, 1886; reviewed by Shorn, G., Ann. trav. pub. Belgique, vol. 4, 1886, pp. 453–495.

He confirmed Hilt's observation that the amount of methane does not depend upon the absolute pressure but on the rapidity of change. If after a rapid diminution of pressure, there was little or no further change, there was only a gradual increase of methane, whereas if after a rapid increase of pressure there was little or no barometric change, there was a slight decrease of methane content. Therefore the time of maximum gas content did not precisely coincide with that of minimum pressure. The curves of barometric pressure and volume of methane showed 105 concordances and 85 discordances.

Koehler made an important test to determine the effect of artificial rarefaction of the air on methane emanation. The intake was sealed while the upcast fan continued to run so as to diminish the air pressure in the mine, which amounted to 2.5 millimeters, or about one-tenth inch. The results were as shown in the table on the following page.

As this mine contained large areas of old workings the great increase of methane in the air from the main upcast may have been in large part derived from them. The workings in the Karl bed, however, were all fresh, and the increase of methane from them was probably due to increased emanation from the solid coal when the atmospheric pressure was diminished. There are some possibilities of error in these diminished-pressure observations because air volumes are not very accurately measureable with anemometers running slowly.

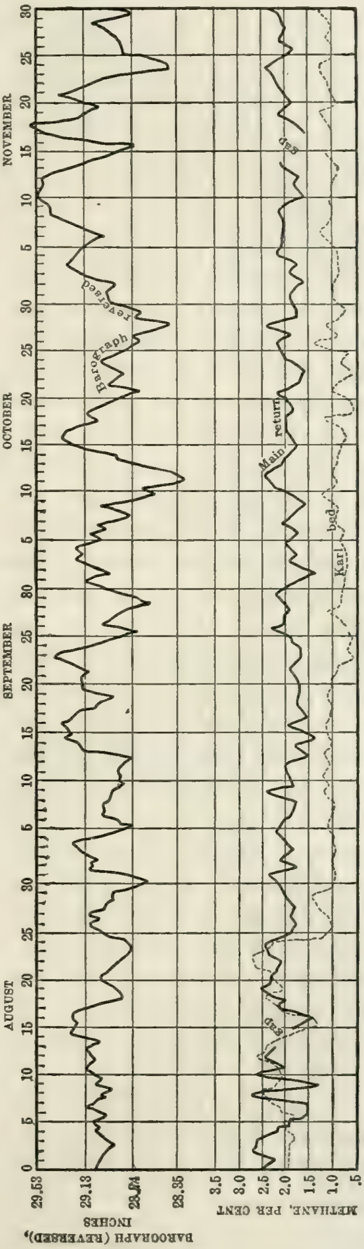

FIGURE 11.—Curves showing variations in percentage of methane and barometric pressure in the Gabriele mine, Karwin, Austria. After Koehler. Full line represents samples collected in main return; dotted line represents samples of return air from workings in Karl bed.

Variation in volume of methane in return airways of Karwin mine under diminished air pressure.

Number of test.	Fall of mercury in barometric pressure.	Point where sample was taken.	Volume of methane at beginning of test.	Volume of methane at conclusion of test.	Increase in methane content.
	Inches.		*Cubic feet.*	*Cubic feet.*	*Per cent.*
First	0.10	Upcast	710	1,301	80
Do	.10	Karl bed	146	206	41
Second	.08	Upcast	725	1,079	50
Do	.08	Karl bed	190	228	20

In 1888 Koehler[a] made another series of similar observations in the Kohlscheid mines near Aachen.

The barometer pressures were taken at noon and midnight and the amount of gas was determined morning and night. A gasometer installed behind the fan of the ventilating shaft of the Ath-Gouley mine, and placed in such a manner as exactly to fill itself in 12 hours, furnished average samples of the composition of the air in the mine. For taking the amount of gas a Coquillion fire-damp meter was used, and the analyses furnished by that apparatus were controlled by experiments at the laboratory of the Aachen School of Mines. The comparison of the curves of methane and atmospheric pressure is very instructive. Thus, for January, 1889, during the first fortnight, to the lowest pressure (737 millimeters) corresponded a maximum holding power of 3.9 per cent of methane, which became nil when the pressure returned to 770 millimeters. During the second fortnight the variations of the curves also agreed. In February a fall of pressure showed itself by an increase of methane up to 7 per cent, and ended by disappearing. Then, the pressure rising, the methane decreased. Sometimes considerable barometric falls appeared to be without effect, but, generally speaking, the maximum of pressure coincided with the absence of methane. In summer escapes were much more marked, and the proportion of 8 per cent was even exceeded at the end of July. The phenomena were not simultaneous, one or two days being necessary for the alteration of the subterranean air to attain its maximum, but there were cases observed in which the action was in some way immediate.

CONCLUSIONS BY BEHRENS.

Behrens,[b] in a review of the observations made by himself and Koehler at Karwin and Hibernia, Westphalia, states the following conclusions:

(1) Increasing atmospheric pressure retards the escape of fire damp; diminishing pressure accelerates it.

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[a] Koehler, G., The relations of barometric depression and escapes of fire damp: Eng. and Min. Jour., vol. 5, p. 287, March 7, 1891; abstracted in Col. Guard., vol. 61, 1891, p. 320.

[b] Behrens, —, Beiträge zur Schlagwetterfrage: Oest. Zeitschr. Berg-Hüttenwesen, vol. 45, 1897, pp. 43–46, 63–67, 74–79.

(2) The greater the increase in atmospheric pressure per unit of time, so much the more is the liberation of gas diminished; the more the pressure falls per unit of time, the larger is the escape of the gas.

(3) If the barometric pressure, having attained a certain height—the result of which has been to diminish the escape of fire damp—remains at that level for some time or permanently, the percentage of gas gradually increases again, though without attaining the original figure, so long as the increased pressure continues. The diminution in the outflow, induced by a permanent increase in the atmospheric pressure, is less when the gas pressure in the coal is high, and greater when the gas pressure is low. Conversely, when the atmospheric pressure falls—which condition is accompanied by an increase in the escape of gas—and then remains at this point, either for some time or permanently, the percentage of gas gradually decreases again, though it does not recede as low as the original level, so long as the pressure remains constant; the increased outflow of gas, due to the permanent fall in the pressure, is smaller when the gas pressure in the coal is high, and greater when the gas pressure is low.

(4) Should a sudden rise of atmospheric pressure be succeeded by a more gradual increase, a slow acceleration of the gas outflow ensues; on the other hand, when a rapid fall in the barometer is followed by a more gradual one, the retardation of the gas outflow proceeds slowly.

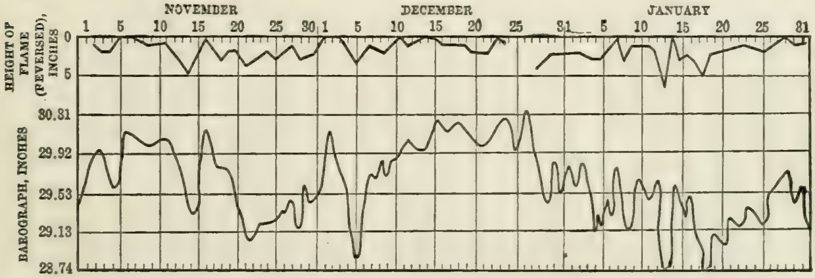

FIGURE 12.—Curves showing relation between length of flame of a blower and variations in atmospheric pressure, November, 1885, to January, 1886, at Hanover mine, Westphalia.

In no case, however, do the maxima or minima of the barometric curves correspond to maximum or minimum rates of outflow of the gas.

TESTS AT HANOVER MINE.

In 1885 Broockman[a] made an investigation at Hanover mine No. 2 near Wattenscheid, Westphalia, to determine the effect of variations in atmospheric pressure on the volume of gas from a "blower." The blower was connected to a tube, and the gas burned so a comparison could be made of variations in height of flame with variations in pressure as recorded on a barograph. The results are given in figure 12, which shows a close connection between the two indicated by an increased flow of gas at the time of diminished atmospheric pressure, as in the tests of mine air at Karwin and other places.

Heise and Herbst[b] have shown that notable pressures of the gas are obtained only by boring several meters back into the solid, and that near the face the pressure is only slightly in excess of the air pressure. This refers solely to the pressure of the free gas and not to the gas in the pores of the coal which escapes too slowly to affect an ordinary gage.

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[a] Broockman, K., Ueber den Einfluss des Luftdruckes auf die ausströmende Gasmenge eines Bläsers, Zeitschr. Berg- Hutt. Salinenwesen, vol. 34, 1886, pp. 155–156; Bull. Soc. l'indus. min., ser. 3, vol. 1, 1887, pp. 624–625.

[b] Bergbaukunde, vol. 1, 1908, pp. 458–461.

INVESTIGATIONS OF THE AUSTRIAN FIRE DAMP COMMISSION.

The Austrian Fire Damp Commission[a] made many observations to ascertain the relation between gas emanation and changes of atmospheric pressure. The tests were made simultaneously for four weeks in six districts, some in gaseous mines, others in nongaseous mines, some in mines with old workings, and others in mines without old workings. Samples were taken three times a day and data obtained as to the amount of coal mined, surface of coal exposed, number of men and animals working, and other details. In some of the returns in gaseous mines the samples contained 1½ per cent of methane or 7,469 cubic feet per ton of coal extracted, and in less gaseous mines the methane content in the return air averaged 0.3 per cent, or 519 cubic feet per ton of coal extracted.

In five districts in gaseous mines without old workings no concordance was found between barometric changes and the amount of methane. In mines in a slightly gaseous district, however, the volume of methane varied from 12½ cubic feet a minute when the barometer was low to 11 cubic feet when it was higher than the average. On the other hand, in mines containing extensive old workings the proportion of methane closely followed the changes in atmospheric pressure. The return air in the old workings of the Tiefbau mine was sampled from February 13 to March 5, 1889, with results shown in figure 13.

The effect of barometric changes on gas emanation from very gaseous fresh coal was tested by measuring the volume of methane from bore holes. It was found that the volume produced from these in equal given times showed no relation to the variations of atmospheric pressure. This latter test, however, did not show fairly the conditions at the exposed surface of the coal, where ordinarily most of the gas has been given off and therefore the pressure is far less than in bore holes.

INVESTIGATIONS IN FRENCH MINES.

The French commission created in 1887 to study coal gas[b] gave considerable attention to the question of the effect of barometric changes. The commission was doubtful as to there being any material effect or enough to be a factor of danger in properly ventilated mines. Le Chatelier, however, believed that old workings were susceptible. Chesneau [a] made daily tests for 11 months in 1886 at the Herin mine at Anzin at a place where only a small part of the air could come from old workings even with great barometric change. The methane content of this air averaged about 0.8 per cent, or equivalent to an outflow of about 118,570 cubic feet a day. He found 81 days of concordance between gas emission and barometric fall, 46 days of discordance, and 51 days of independence. (See fig. 16, p. 100.) He concluded that for a bed that yields a permanent and relatively regular outflow of gas sudden barometric falls cause a notable increase in the emanation of methane.

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[a] Atkinson, W. H., The report of the Austrian Fire Damp Commission: Trans. Fed. Inst. Min. Eng., vol. 3, pp. 531, 1891–92, and Chesneau, G., Annales des mines, ser. 9, vol. 1, 1892, pp. 245–248.

[b] Goupillière, Haton de la, Rapport présenté au nom de la commission d'étude des moyens propres à prévenir les explosions du grisou: Annales des mines, ser. 7, vol. 18, 1880, pp. 193–415.

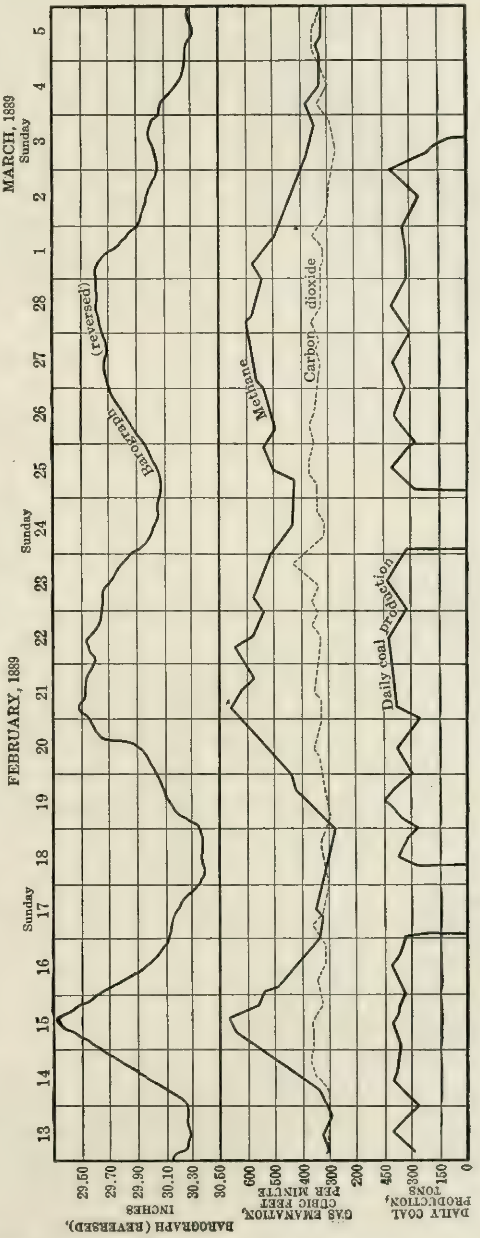

FIGURE 13.—Curves showing variations in volumes of methane and carbon dioxide in return air at Tiefbau shaft, Austria, showing relation of variations in atmospheric pressure and also of amount of coal mined.

TESTS AT LIÉVIN.

In 1907 Morin [b] made an extended investigation to ascertain the relation between atmospheric pressure and gas at Liévin, France. A long time previously he had noted such relation, especially in certain galleries not well aired and also along some of the returns.

The tests at Liévin were continued for two months. In shaft 13 the percentage of gas was determined every hour, with the unfortunate exception of Sundays, and in three shafts every eight hours. At shaft 13 the upcast from an area of nearly 200,000 square yards, including extensive worked-out areas, carried 16,800 cubic feet of air a minute with remarkable uniformity. The samples of air were collected by displacement in water-filled bottles. Except for a small area in an underlying bed there were no workings above or below. The principal results are presented in figure 14.

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[a] Chesneau, G., l'Influence des mouvements du sol et des variations de la expression atmosphérique sur les dégagements de grisou: Annales des mines, ser. 8, vol. 13, pp. 389–428.

[b] Morin, Léon, De l'influence des variations de la pression atmosphérique sur les dégagements de grisou: Annales des mines, vol. 16, ser. 10, 1909, pp. 385–437; abstract in Eng. and Min. Jour., vol. 90, Sept. 17, 1910, p. 565.

Morin's deductions from these results were as follows:

Even slight variations in atmospheric pressure may induce variations in the escape of methane, and other things being equal, when the atmospheric pressure remains constant the liberation of methane is uniform. When atmospheric pressure increases the escape of gas diminishes, and conversely.

Maximum atmospheric pressure corresponds to minimum percentage of gas and vice versa.

In some tests a decrease of 1 inch in the height of the mercury column increased the proportion of methane 50 per cent.

ATMOSPHERIC CONDITIONS IN OLD WORKINGS.

As the air tested came from a district comprising a large area of old workings, it appeared likely to Morin that the old workings might act as a great reservoir and give a large outflow of gas at times of diminished atmospheric pressure. Even where the old chambers were filled with gob and the surface had settled more or less the amount of free space was large. He found that when certain old workings were pumped out the volume of water when measured showed that the voids amounted to 30 per cent of the original excavation. A careful estimate of voids in workings in the Du Souich bed, workings which covered nearly 200,000 square yards and were nearly 5 feet high, showed a total of 4,028,000 cubic feet. It was found that if differences in the volume of gas coming out of the mine under different pressures were all supposed to be caused by the open workings the volume of pure methane in the voids in the mine, if the voids were assumed to be filled, would range from 107,660 to 10,266,100 cubic feet, the larger volume corresponding to a longer period of time. This result could be explained only by the hypothesis that the gas and air might be in strata of varying composition, those mixtures richest in gas occupying the highest levels. Under such a condition a slight diminution in atmospheric pressure might affect only the mixtures poor in gas occupying the lower levels, whereas further diminution would bring out mixtures containing more gas. However, careful sampling of the air in the old workings did not reveal such a condition, which moreover is not consistent with the laws of diffusion. Therefore Morin concluded that in these experiments the old workings were not the only cause, nor even the most important one in the variation of the amount of methane found.

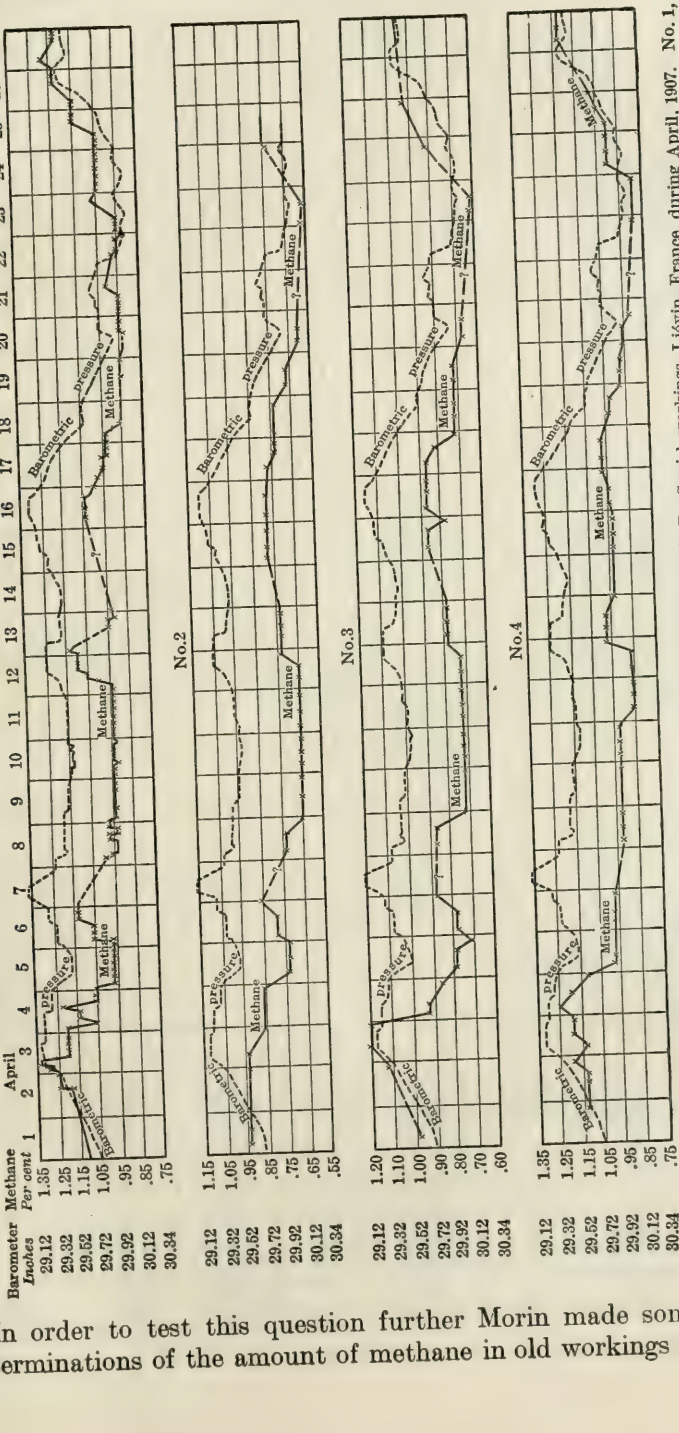

FIGURE 14.—Curves showing variations in percentage of methane and barometric pressure in Du Souich workings, Liévin, France, during April, 1907. No. 1, return 13 at 534-meter level, 16,800 cubic feet a minute. No. 2, south return air at 345-meter level, 14,076 cubic feet per minute. No. 3, east return air at 345-meter level, 7,653 cubic feet per minute. No. 4, return air in No. 4 gangway at 430-meter level, 4,748 cubic feet per minute.

In order to test this question further Morin made some precise determinations of the amount of methane in old workings at Liévin.

In a chamber in the most gaseous part of the mine, a tube 16 feet long was fastened along the roof and the chamber was then filled with gob. The end of the tube that projected into the gangway was plugged. After three months, samples drawn from the pipe contained as much as 0.46 per cent methane. A similar experiment in another chamber gave 0.75 per cent. Meanwhile the amount of methane in the ventilating currents in returns near by varied from 0.3 to 0.6 per cent. In old workings in another part of the mine where the ventilation was mostly cut off, some of the air from the gob was found to contain 2 to 2.7 per cent of methane. These tests indicate that although some gas is given off by old workings, even if closely filled, it does not increase to any important extent the volume in the returns. No air rich in gas could be obtained from any part of the old workings at Liévin even though sampling pipes were placed close to the roof and in the highest places.

At one stage of Morin's observations the ventilation of the mine was changed, with the result that when the volume of air passing through one of the main returns was diminished, the proportion of methane became only 0.4 per cent. Samples of this air taken at intervals, therefore, did not show any concordance with change of atmospheric pressure, although the air traversed a considerable area of old workings. In some working faces considerable gas came from inclosing strata, but the amount was variable and a much greater volume came from the coal in the face and from piles of broken coal.

RELATION OF BAROMETRIC PRESSURE TO AMOUNT OF GAS FROM FRESH COAL SURFACES.

In order to determine whether there was any relation between the barometric pressure and the amount of methane given off by fresh coal surfaces Morin made a series of tests of the return air from an individual chamber. The place selected was in the deep-lying Leonard bed and the return air fron it was sampled every hour for two days, with the following results:

Percentages of methane at various atmospheric pressures in chamber in Liévin mine.

Barometric pressure of mercury.	Volume of methane per minute.	Barometric pressure of mercury.	Volume of methane per minute.	Barometric pressure of mercury.	Volume of methane per minute.
Inches.	*Cubic feet.*	*Inches.*	*Cubic feet.*	*Inches.*	*Cubic feet.*
29.72	17	29.90	18½	30.16	12
29.74	12	29.94	20	30.16	17
29.76	16	29.98	26	30.18	18
29.78	34	30.02	26	30.20	22
29.80	21	30.04	28½	30.24	34
29.84	27	30.08	26	30.26	33
29.84	15	30.08	26	30.28	38
29.86	15	30.10	26	30.30	31
29.88	13	30.12	22	30.32	41

This series of observations shows no relation whatever between the atmospheric pressure and the volume of methane given off, but the gas may have been coming out of the coal at this place at such pressure that the volume was not affected by the gradual ½-inch rise of the barometric pressure.

EFFECT OF SETTLING OF ROOF AND FLOOR.

The negative results of this test, confirming the supposition that the high internal pressure of the gas in the solid coal would not be affected by barometric change, and the lack of evidence that any great amount of gas came out of the gob and old workings, led Morin to conclude that the variations in the rate of escape of the gas were due to other causes. He suggests, therefore, that the barometric changes must mainly affect the volume of gas coming from floor and roof, whether this gas is contained in the rocks themselves or comes from fissures connected with adjoining coal beds. He points out that as the coal is removed the roof settles and the floor tends to rise, causing fractures from which gas from adjoining virgin coal may enter the workings. The pressure affecting the flow of gas through such fractures is independent of the original pressure in the relatively impermeable coal and may be so light as to be closely balanced by atmospheric pressure. Morin believes that this source of gas is the most susceptible to atmospheric changes and is responsible for the great variations in volume of methane which are illustrated in figure 15.

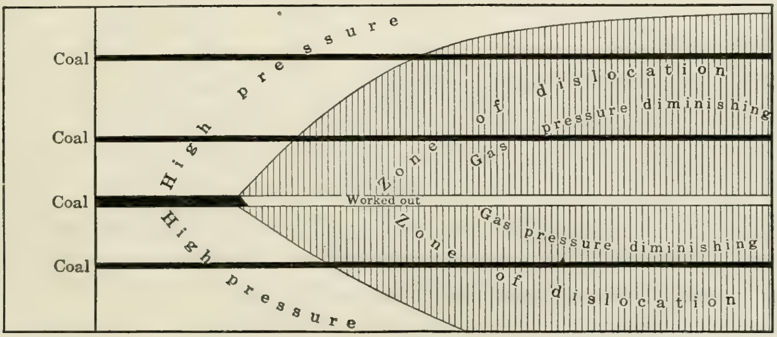

FIGURE 15.—Ideal section through coal workings showing area in which flow of gas is affected by removal of coal.

RELATIVE VOLUMES FROM DIFFERENT WORKINGS UNDER VARIOUS CONDITIONS.

In order to ascertain the relative amounts of methane given off by workings of various kinds and extents under changing atmospheric pressures Morin collected samples of return air from various splits of return No. 1 at Liévin before and after a barometric fall from 30.72 to 29.12 inches, December 6 to 14, 1907. The results were as follows:

Volumes of methane in returns to shaft No. 1 at Liévin, Dec. 6 to 14, 1907.

Return.	Surface uncovered.	Voids in old workings.	Volume of methane per minute.[a]		Remarks.
			Dec. 6, barometer, 30.12 inches.	Dec. 14, barometer, 29.12 inches.	
	Sq. yards.	*Cu. yards.*	*Cubic feet.*	*Cubic feet.*	
Main return to shaft No. 1			247	247	
Arago, at 534-meter level			13	13	Gangway 1,300 feet long with blower.
Auguste, N return	3,600	1,703	4	4	Small workings with rise of 800 feet.
Frederic, H return	27,600	14,410	13¾	19½	
Du Souich at 476-meter level.	18,000	15,720	20	25	
Auguste, 31 return	31,200	19,650	7	7	Overlying and underlying bed worked out.
Edouard couchant return F	25,200	20,960	18½	21	
Frederic, return 200	40,800	21,339	16	37	
Auguste and Du Souich return 0.	43,800	24,628	19	27	
Du Souich return 200	42,000	30,130	16	24	
Alfred return at 345-meter level.	90,000	52,400	19	24	
East return at 345-meter level.	109,200	68,120	22½	49	
Alfred at 476-meter level	114,000	78,000	21½	30	
East return at 283-meter level.	166,800	103,490	28	83	
South return at 345-meter level.	180,000	144,100	109	128	
South return at 283-meter level.	391,200	262,000	171	223	

[a] Approximate.

These results show that volume of gas in old workings is not the sole factor to consider. In all the workings but those on Auguste return No. 31 the adjoining beds had not been mined. Old workings in beds of coal equally gaseous and worked to the same extent gave off greatly different amounts of gas from the same volume of voids under the 1.6 inch of atmospheric variation shown in the table. The volume of gas in airway 31 from workings No. 1 in the Auguste bed and from workings in adjoining beds did not vary during the great fall of pressure. On the other hand, in airway 200 the methane from workings in the Frederic bed, which are undermined in about the same area by workings in the Du Souich bed, 50 feet below, was more than double that from the Du Souich workings; also the volume of gas from the latter workings varied less with the change of atmospheric pressure, indicating an escape of gas upward from the Du Souich bed to the Frederic bed workings.

The volume of gas in Auguste airway N, which drains a small area of workings and a rise 800 feet long, did not vary; neither did the volume of gas in the air from the Arago bed, in which a gangway 1,300 feet long was in progress and over which there were many blowers. In this case the emission of gas from coal in place and from blowers was not affected by a great change of atmospheric pressure.

CONCLUSIONS DERIVED FROM RESULTS OF TESTS AT LIÉVIN.

The tests show that the virgin coal is only slightly permeable and therefore the gas pressure in the rock strata affected by the mining is independent of the pressure in the virgin coal, so that as the gas is drained by advance of the workings the pressure becomes feeble. From the facts observed the following conclusions are drawn:

1. The pressure and volume of gas in the rock strata (near the working face) is low.
2. The coal beds are less gaseous near the working faces than in more remote parts and in certain cases the drainage of the beds is complete and the last of the gas escapes under feeble pressure.
3. The coal beds far from workings remain gaseous.
4. The strata affected by coal workings, even though distant, contain little gas, and in consequence after a settling of roof or rise of floor the gas pressure in the zone of fracturing remains very feeble.

Morin gives essentially the following résumé of the experiments in the Du Souich bed:

The quantity of gas liberated does not depend alone on the amount of change of barometric pressure, but also on the absolute pressure, and therefore becomes proportional to the time between the two extremes of pressure limiting the fluctuation. When a period of constant atmospheric pressure followed a fluctuation the proportion of gas remained at the figure that it had reached as a result of the fluctuation (see curves in No. 1, fig. 14). A low or a high pressure lasting for several hours induced a maximum or a minimum proportion of gas lasting for the same length of time. A given pressure was not always attended by the same proportion of gas because of complications caused by the effects on the atmosphere in old workings. After an increase to a given atmospheric pressure the percentage of gas was smaller than after a diminution to the same pressure. He suggested that probably this could be explained by the supposition that during a period of high pressure the gas accumulates in old workings, whence during periods of low pressure the gas flows out into the returns.

Finally Morin concludes that variations in gas outflow induced by fluctuations in atmospheric pressure are due not only to old workings but also to gas from adjoining strata (roof and floor) and from fissures through these strata which admit gas from adjoining coal seams.

OBSERVATIONS IN ENGLAND AND THE UNITED STATES.

At a meeting of the Midland Institute of Mining Engineers one of the mine managers [a] stated that when the mine was hot—that is, had relatively high temperature—the presence of methane was less evident, but when an increased volume of cold air was introduced the proportion of gas increased rapidly. This had been noted many times. Therefore, the variations of temperature must have had a close relation to the amount of gas given off in this mine.

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[a] Anon. The barometer as an indicator of gas in collieries: Min. and Sci. Press, vol. 34, 1877, p. 10.

For several years at the Auchincloss mine, near Nanticoke, Pa., a comparison was made of barometer readings and daily reports of fire bosses as to the amount of gas in the headings, and it was found that there was no relation between them. The mine is relatively new, without large areas of old workings.

TESTS WITH SAMPLES OF PENNSYLVANIA COAL.

In tests to determine the amounts of gas given off under diminished pressure Chamberlin [a] obtained some results that throw light on the effect of barometric changes. The relative amounts of gas given off by bituminous and anthracite coals under long-continued low pressure were compared with those obtained at ordinary air pressure. Two samples were taken, one of bituminous coal from the Mansfield mine, Carnegie, Pa., and one of anthracite coal from Nanticoke, Pa. Each sample was divided into two parts, one of which was placed in a vacuum bottle from which the air was pumped; the other was sealed in a bottle at ordinary air pressure. All the bottles were submerged in water. After seven days the anthracite samples were tested and in both bottles the methane evolved was 1.07 times the volume of the coal. At the end of 10 days the bituminous coal kept in a vacuum had given up 0.25 of its volume of methane, whereas the sample under ordinary air pressure had given off only 0.14 times its volume. As the amount of methane evolved in the air-filled bottles was greater than the volume of oxygen absorbed from the air by the coal, the final pressure was slightly greater than the barometric pressure toward the close of the test.

In these experiments the diminished pressure appeared not to have increased the emanation of gas from the anthracite. Chamberlin decided that barometric variations that do not exceed 1½ inches can not have much effect on gas escaping from the interstices of the coal, and that time was the principal factor in the escape of gas. Blowers and feeders escaping under low pressure from fissures are naturally much more sensitive and might be affected by barometric changes.

EFFECTS OF EARTH MOVEMENTS ON METHANE EMANATION.

Many suggestions have been made as to the effects of earthquakes, sun spots, and other natural phenomena on the emanation of gas in coal mines, but most of the evidence presented is not convincing.

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[a] Chamberlin, R. T., Notes on explosive mine gases and dusts, with especial reference to explosions in the Monongah, Darr, and Naomi coal mines: Bull. 26, Bureau of Mines, pp. 37–39; reprint of U. S. Geol. Survey Bull. 383.

Several papers on the subject give comparative statistics of explosions, overlooking the fact that many of them are caused by coal dust and due to some mishap in the mine that would produce the same result at any time. The suggestion that variations in atmospheric pressure cause an up-and-down movement of the earth's crust, which changes the conditions of gas emission, may have some bearing. Darwin[a] estimates that very high barometric pressure—good weather conditions—may bend down the earth's crust 3 or 4 inches, and conversely diminished pressure may be followed by expansion. The latter might cause the opening of crevices and let out gas, especially where mining has set up uneven stresses in the strata. Gas being under great pressure in the strata its emission might be influenced by a cause of this kind.

Milne[b] has presented an extended discussion of the effect of the earth pulsations due to meteorological influences. He cites experiments of Chesneau[c] at Anzin, in France, who for many months noted relative movements of a tromometer and amount of methane given off. The relation was well marked in some cases but in general it kept pace with barometric changes.

In figure 16 are shown results of some of Chesneau's observations made for 11 months in the gaseous workings of the Herin mine near Anzin. The curves show the percentage of methane, barograph readings, and the tromometer record of earth tremors. The latter were mostly very slight, except the notable pulsation on December 8, which was at a time of rapidly diminishing atmospheric pressure and attended by great increase in methane content in the return air. The details from December 6 to 10 are shown on a large scale in figure 17.

Articles advocating the belief in a relation between seismic disturbance and mine explosions have been published by Beard,[d] Spalding,[e] Stow,[f] and others.

From a consideration of the evidence presented it appears to the author that earth movements can not affect the emanation of methane unless possibly to precipitate an outburst that is nearly ready to take place; ordinarily a blast in a near-by chamber would cause much more local movement.

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[a] Darwin, G. H., On mechanical effects of barometric pressure on the earth's surface: Rept. British Asso. Adv. Sci., 1882, pp. 106–111.

[b] Milne, J., On earth pulsations and mine gas: Trans. Fed. Inst. Min. Eng., vol. 5, 1893, pp. 203–230.

[c] Chesneau, G., and others, De l'étude des mouvements de l'écorce terrestre poursuivie particulièrement au point de vue de leur rapports avec les dégagements de produits gazeux: Annales des mines, ser. 8, vol. 9, 1886, pp. 207–281; and

Chesneau, G., De l'influence des mouvements du sol et des variations de la pression atmosphérique sur les dégagements de grisou: Annales des mines, ser. 8, vol. 13, pp. 389–428.

[d] Beard, J. T., Colliery explosions and their causes * * * in which seismic forces are believed to be more important than barometric changes: Eng. and Min. Jour., vol. 83, 1907, pp. 1051–1054.

[e] Spalding, W. A., Mine explosions as related to earthquakes: Eng. and Min. Jour., vol. 87, 1909, pp. 411–413.

[f] Stow, A. H., Seismic disturbances and coal-mine explosions: Eng. and Min. Jour., vol. 88, 1909, pp. 449–450.

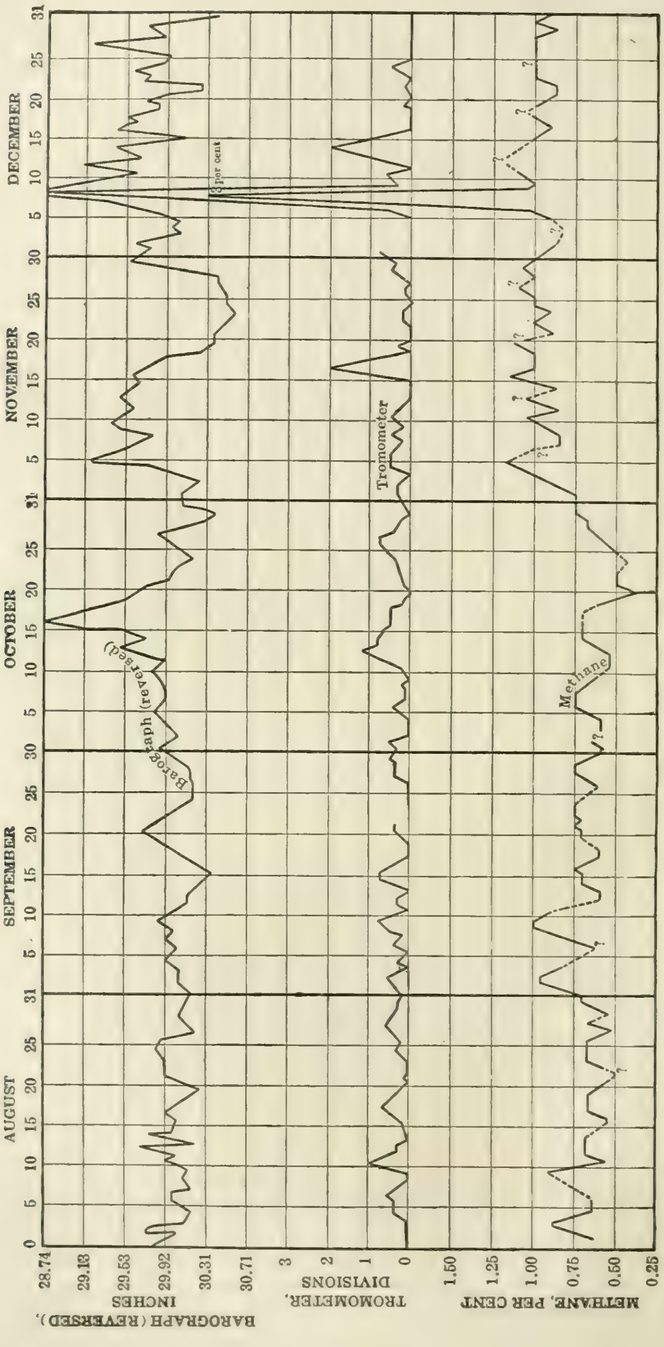

FIGURE 16.—Curves showing variations in atmospheric pressure, percentage of methane in return air, and earth tremors at the Herin mine, Anzin, France, August to December, 1886.

DURATION OF METHANE EMANATION FROM COAL.

Many of the facts stated on previous pages show that coal loses the greater part of its gas content while it is being mined and broken, and in the same way much of the gas in the coal exposed in faces, ribs, and pillars drains off rapidly. In the mine, however, this drainage of gas is superficial, for at greater or less depth the solid coal contains its ordinary volume. This gas is disposed to flow to the exposed surface, but the rate of movement must depend on the pressure and volume of the gas and the porosity and solidity of the coal. In general, in gaseous places it is found that the gas emanation is rapid when the workings are progressing rapidly, but after awhile as the district is opened, the volume of gas greatly diminishes. It is a frequent practice in gaseous mines to extend gangways rapidly into gaseous places to effect a general ventilation and then to leave the place for awhile until the gas diminishes so that mining ceases to be dangerous. Slight cracking of roof and floor facilitate gas escape and in some cases it gives rise to feeders. The diminution of methane emanation is shown by the fact that in many mines after Sunday cessation or any other shutdown the amount of gas diminishes. There are many examples of gaseous beds that have yielded little gas in areas where the adjoining beds have been worked out, the gas having drained off through cracks and porous strata.

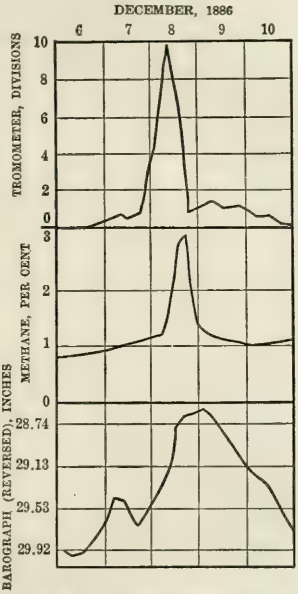

FIGURE 17.—Curves showing variations in atmospheric pressure, percentage of methane in return air, and earth tremors at Herin mine, Anzin, France, December 6 to 10, 1886.

GAS DRAINAGE IN MINING.

The project of tapping off gas in gaseous districts is one that many coal engineers have considered and occasionally have carried into practice. In many mines it has been found desirable to extend gangways rapidly through a gaseous district and then after ventilation has been established to let the gas draw off for weeks or even years before general mining is begun. Working out an overlying bed in order to drain off gas from the lower one is often tried, but the efficacy of drainage depends on the permeability of the intervening strata. The extension of bore holes horizontally in the coal bed or from the surface above is a promising expedient, but in most cases it does not draw much gas from solid coal because the surface exposed is too small and gas travels through the coal too slowly to affect a wide area. This has been proved by tests of pressure and volume from bore holes; after a hole has been opened a long time and then closed the pressure is soon the same as the original. Many tests have been made of drainage holes in European mines, but the results have been entirely unsatisfactory. Some experiments by Lange[a] in Rochebelle mines, France, to drain off carbon dioxide by bore holes were unsuccessful. Old workings, however, have been drained by tubes sunk from the surface, sometimes to great advantage. The author observed an instance of this in the Otto colliery, 5 miles west of Pottsville, Pa., where tubes tapped the top of workings in inclined beds and a very large volume of methane was brought up by escaping air from a small ventilation split. The proportion of gas was so high that the mixture could be lighted and would burn for hours.

RELATION OF METHANE CONTENT TO CHARACTER OF COAL.

The investigations having shown that the amount of methane in coal varies greatly in different coal beds in the same series and in different parts of the same bed, we conclude that the original methane content is closely related to the constituents of the original deposit, possibly modified somewhat by conditions under which the coal was formed. In making comparisons, however, the original amount of methane should be taken into consideration, because many parts of the coal bed that may have been very gaseous when they were formed have lost more or less of the gas by drainage to the surface. Such drainage through overlying strata takes place partly by percolation and in part by crevices due to fracture. It is also a fact that the gas emitted in outbursts, blowers, and even in notably gaseous workings is not always an indication of the total amount of methane in the coal that may be given off in time. No relation has yet been found between the proportion of methane and the texture of the coal or of the components as indicated by chemical analyses, for coals high in volatile constituents are not the highest in methane. Undoubtedly the original vegetal material now represented by coal varied greatly in character in different places and at different times even in the same basin, and the rate of decomposition and of burial by later deposits and the nature of these deposits varied greatly and these variations had much to do with the development of gases. It is the author's belief that a relation will be found between methane content, or at least the original methane content, and the organic constituents of the coal, and it is along this line that future detailed study of the problem should be directed.

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[a] Lange, C., Les dégagements d'acide carbonique aux mines de Rochebelle: Bull. Soc. l'indus. min., ser. 3, vol. 6, 1892, pp. 1141–1180.

PROBABLE ERROR IN FIGURES FOR METHANE CONTENT IN MINE AIR.

In most records of the proportion of methane in mine air the figures are given to the second place of decimals and even with greater apparent precision. In an investigation of the probable accuracy of ordinary methane determination G. A. Burrell,[a] chemist of the Bureau of Mines, has found that the probable error is nearly 0.03 per cent. Accordingly, in two analyses reported as 0.17 and 0.19 per cent, for example, the amount of methane may be the same, or the first may be 0.19 per cent and the second 0.16 per cent. This probable error invalidates all arguments based on such small differences as 0.03 per cent. When this probable error is calculated into cubic feet per minute the error increases, for air volume determinations are necessarily somewhat inaccurate. Usually the area of cross section is not precisely determinable or determined. Most anemometers have an error of at least 1 per cent; in many of them the amount is much greater, and moreover the actual velocity of the air current varies in different parts of the cross section. Probably the ordinary determination of volume of air per minute has an error of at least 5 per cent. That is, a current reported as 10,000 cubic feet a minute may be anywhere between 10,250 and 9,750 cubic feet. Therefore, in such a volume of air analyzing 1.0 per cent of methane the true amount of that gas is between 102¼ and 97½ cubic feet per minute. This is not allowing for probable error of analysis, by which the true proportion may range from 1.01 to 0.98 per cent, so that the true volume of methane in this instance is between 103.5 and 95.3 cubic feet a minute, a possible difference of 8.2 cubic feet, or nearly 0.1 per cent, if the errors are all negative. It is the author's belief that it would be safe to assume a possible error of 0.1 per cent in all the reports of volume of 50 cubic feet or more and a somewhat larger error for smaller amounts, increasing rapidly to 50 per cent when the reported methane percentage is near 0.03 per cent. Velocity movements are also less reliable when very low or very high, especially where the cross section is large and irregular.

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[a] In a letter to the author.

EXPLOSIVE GAS IN THE NORTHERN ANTHRACITE COAL FIELD OF PENNSYLVANIA.

INTRODUCTION.

In beginning the investigation of the conditions under which explosive gases occur in coal beds in the United States, the anthracite coal field of Pennsylvania was selected on account of the structural conditions presented there. As one of the objects of the investigation was to determine whether there was any relation between methane emanation and the structure of the coal measures, the many flexures of the anthracite beds and the great extent of the mine workings in them led to the selection of such beds for study. A general examination of the entire anthracite region led to the conclusion that the most instructive results would be obtained by a detailed study of certain typical gaseous mines in the northern basin near Wilkes-Barre and Scranton. The results are presented in the following pages.

Some of these mines produce large volumes of methane, several giving off 2,000 to 3,000 cubic feet a minute. The gas is brought to the surface by the ventilating fans and constitutes 1 to 2 per cent of the return air. The volume of methane issuing from three mines at Wilkes-Barre is 9,000,000 cubic feet a day, a volume equal to that of the illuminating gas from a plant supplying a city of 300,000 inhabitants.

In making the investigation attention was given to the effect of depth, of the nature of the beds overlying the coal, and of the area of coal surface exposed, on the occurrence of gas in the mines. Many samples of return air were taken and sent to the Pittsburgh laboratory of the Bureau of Mines, where they were analyzed. These samples were collected in December, 1910, and January, 1911, and some supplemental sampling was done for the author by H. I. Smith, assistant mining engineer of the bureau, in February, March, and April, 1912. Later, in April, 1912, after mining had been suspended nearly a month, the author again visited certain mines and resampled the air to obtain data for comparison with previous samples taken when the mines were in operation. By this means it was possible to ascertain the influence of a cessation of mining on the escape of methane.

Anthracite is fully as gaseous as bituminous coal, and so far as can be seen the gas occurs under the same conditions in both classes of coal. In a test made of a sample of anthracite from a mine at Nanticoke, Pa., the gas given off was more than three times the volume of the coal and some had been lost in mining, etc. In the northern anthracite basin small gas explosions occur nearly every day, and although many of them do no great damage, yet men are fatally burned in some of them. In the 11 years from 1899 to 1909, the number of deaths from explosions of coal gas in the anthracite mines was 245; of these about four-fifths were in Luzerne County. In each of these explosions the body of gas was small and only a few persons were killed, some by burning and others by afterdamp. The mine operators have to use great precaution to insure complete ventilation in all working chambers of the mines, and in some districts a large volume of air has to be forced through the mine to dilute the gas below the danger point. According to the report of the department of mines of Pennsylvania, the volume of air discharged from all the mines in the northern basin is nearly 31,000,000 cubic feet a minute, most of it being drawn by fans driven by steam or electric power.

As the average daily output of coal from the basin is about 131,000 tons, the volume of air for ventilation is equal to about 341,000 cubic feet for every ton of coal mined.

The number of mines is about 200 and the total number of men underground nearly 64,000. The State law requires 200 cubic feet of air per person in the mine, but in nearly all mines this amount is greatly exceeded and in the gaseous district about Wilkes-Barre three to four times this amount is used. The gross volumes in each district, as measured in upcasts, is given in the following table, which shows also the number of miners. The amount of methane in these returns varies from an almost imperceptible trace to 2 per cent. It is not possible to estimate the average proportion of methane, but in the proportion of 0.1 per cent, which is not excessive, there would be in the returns from all these mines about 31,000 cubic feet of methane a minute or 5,760,000 cubic feet a day, weighing 130 tons.

Volume of air and number of miners in the mines in the northern anthracite coal basin.[a]

District.	Air (upcast) per minute.	Number of miners.
	Cubic feet.	
1. Coal Brook to Sterrick Creek mines	2,433,250	6,232
2. Olyphant to Legett Creek mines	2,586,703	6,748
3. Scranton region	3,080,691	6,045
4. Bellevue to Minooka mines	2,433,616	6,240
5. Old Forge to Austin mines	2,002,708	5,322
6. Barnum mine to Reliance mine	3,085,334	7,590
7. Wilkes-Barre region	5,129,532	6,832
8. Exeter to Kingston No. 4 mine	3,371,389	6,140
9. Kingston colliery to Chauncey mine	3,791,800	7,796
10. Susquehanna Coal Co. 5-7 Wanamie-West End mines	2,991,182	5,043
Total	30,906,705	63,988

[a] Compiled from report of Department of Mines of Pennsylvania for 1909.

GENERAL STRUCTURE OF THE NORTHERN ANTHRACITE BASIN.

The northern anthracite field in Pennsylvania is a narrow canoe-shaped basin, 55 miles long on a general northeast course, 6 miles wide at its widest part and tapering to a point at either end. The coal measures are in a syncline that is flat-bottomed and regular to the northeast but more closely and deeply flexed and crenulated to the southwest. The thickness of the coal measures in this syncline is nearly 1,000 feet in the northern part about Scranton, and more than 2,200 feet in the deep basins southwest of Wilkes-Barre. The rocks are largely sandstone and "slate," and about 10 beds of coal now regarded as workable occur at irregular intervals in the measures. The general succession in two parts of the field is shown in figure 18.

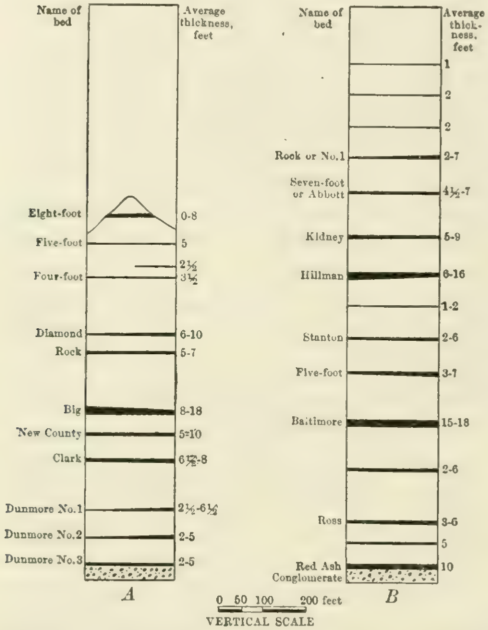
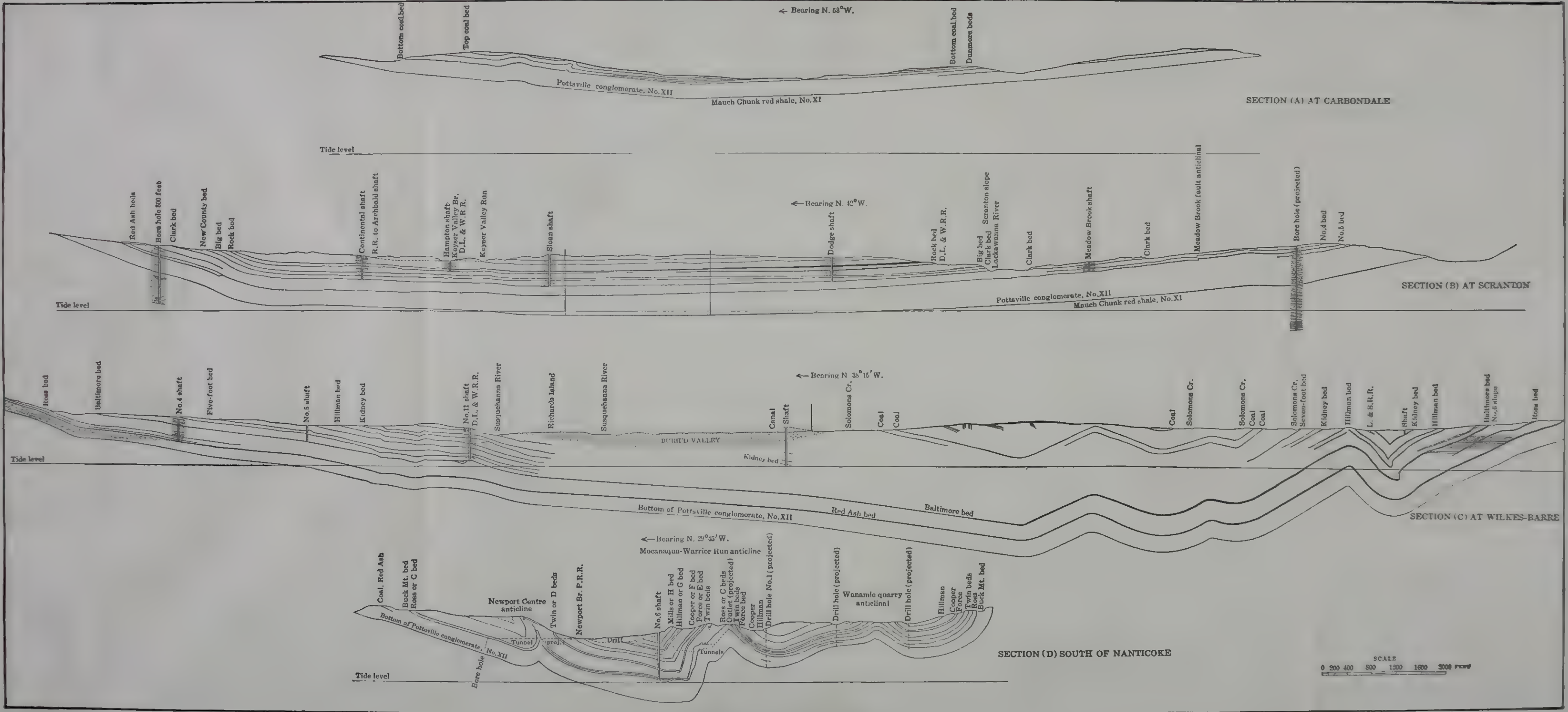


FIGURE 18.—Columnar sections showing stratigraphic position of coal beds in northern anthracite basin. *A*, near Scranton; *B*, near Wilkes-Barre.

These beds have all been mined and in places some of them have been removed under areas of considerable extent. It has been estimated that the total original amount of coal was 5,666,219,784 tons and that up to the end of 1912 slightly more than 1,000,000,000 tons had been removed. The present production is approximately 50,000,000 tons a year.

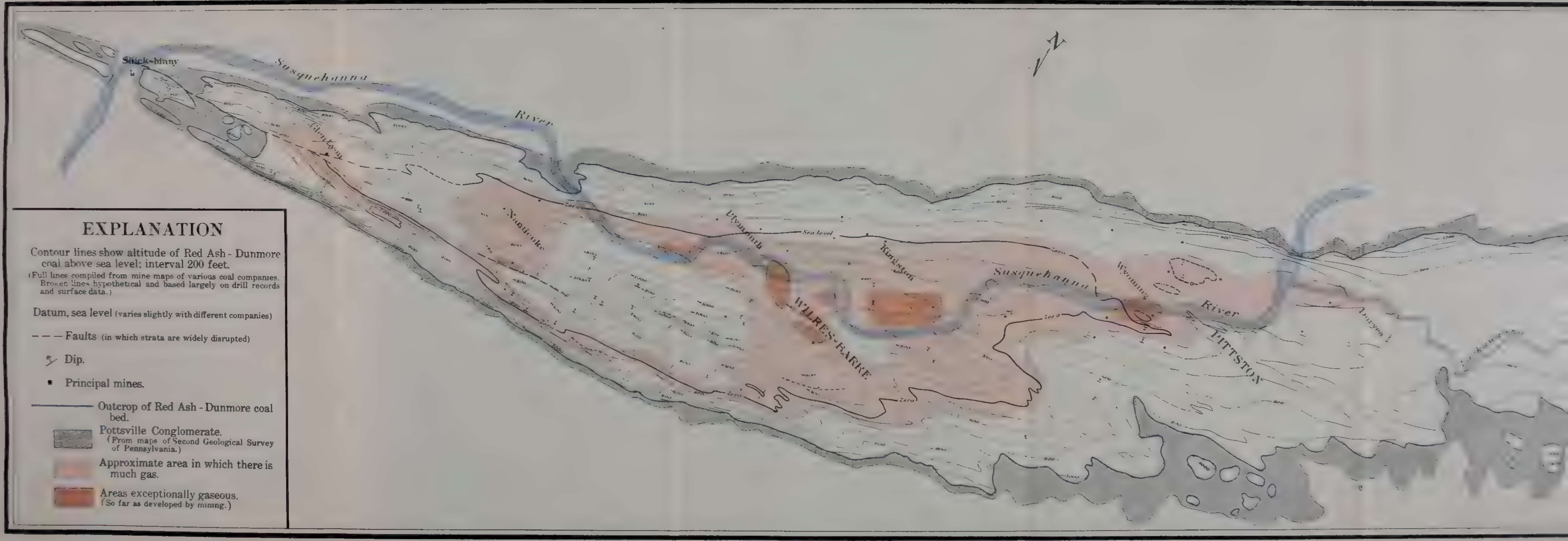
The coal beds lie at various depths, according to their position in the measures and the geologic structure; they all outcrop at either end of the basin and along the sides. In a wide area in the Scranton region the lower coal beds lie between sea level and 300 feet above sea level or 500 to 700 feet deep, but near Pittston and Wilkes-Barre where there are deep flexures they are 1,000 to 1,500 feet below sea level, or 1,500 to 2,200 feet below the surface. The general structure of the basin at intervals along its length is shown in the cross sections in Plate I and by the contour lines in Plate II.

The contour lines in Plate II were traced from a map showing the structure of the basin in detail, which is to be published later. In



CROSS SECTION OF THE NORTHERN ANTHRACITE COAL BASIN.

BUREAU OF MINES
A. HOLMES, DIRECTOR



EXPLANATION

Contour lines show altitude of Red Ash - Dunmore coal above sea level; interval 200 feet.
(Full lines compiled from mine maps of various coal companies. Broken lines hypothetical and based largely on drill records and surface data.)

Datum, sea level (varies slightly with different companies)

- - - Faults (in which strata are widely disrupted)

Dip.

● Principal mines.

—— Outcrop of Red Ash - Dunmore coal bed.

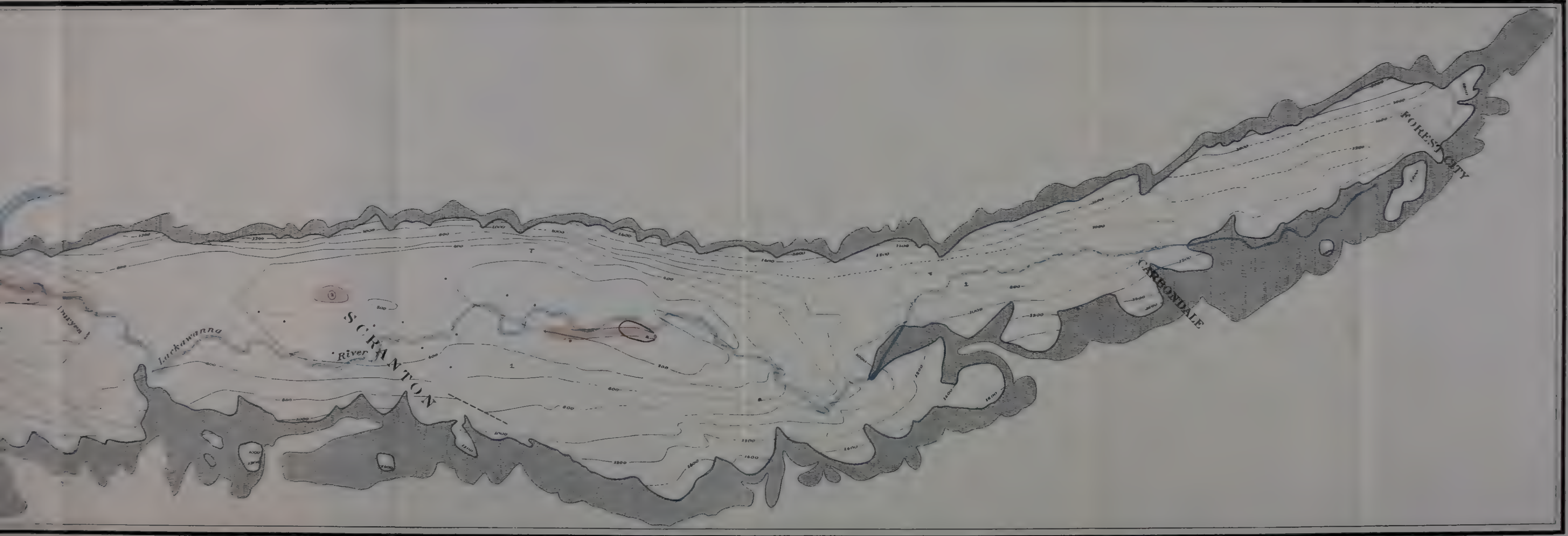
▨ Pottsville Conglomerate. (From maps of Second Geological Survey of Pennsylvania.)

▨ Approximate area in which there is much gas.

▨ Areas exceptionally gaseous. (So far as developed by mining.)

STRUCTURAL MAP OF THE NORTHERN ANTHRACITE BASIN, SHOWING SOME CO

By N. H. Darton



NTHRACITE BASIN, SHOWING SOME CONDITIONS OF DISTRIBUTION OF METHANE.

By N. H. Darton

order to determine the relations between the occurrence of gas and the structural features, a complete compilation was made of the position of the coal beds as shown by mine maps, especially of workings in the lower beds and further data were obtained from many bore-hole records kindly made available by officials of the various companies. From this material contour lines were drawn to show the configuration of the lowest important coal bed, which is called the Red Ash in the Pittston-Shickshinny region and the lower Dunmore in the Scranton region. In certain areas in which no mining had been done, and in places where only the upper beds have been mined, the structure had to be inferred by various means and the hypothetical contours are represented by broken lines.

COLLECTION OF MINE-AIR SAMPLES.[a]

Samples of mine air were collected in bottles which were taken down in the mine and filled with mine air by pumping out the contained air with a rubber-bulb aspirator. In some of the work half-pint bottles with glass stoppers were used, the stoppers being slightly greased to insure a close fit. In many cases the stoppers were either sealed by dipping in paraffin or tied by a loop of cord. They were placed in boxes and so wedged by soft paper packing that there was no chance for the stoppers to shake loose. In other mines bottles such as are made for holding citrate of magnesia were used; these had the usual stopper of porcelain and rubber washer held down by the latch of the wire loop. They were sealed with paraffin. A few tin bottles with tubular ends closed by rubber tubes and glass plugs were used, but these were liable to leakage unless handled with special care. Bottles closed with sound corks boiled in paraffin and sealed with paraffin were found satisfactory when citrate of magnesia bottles were not obtainable. The rubber-bulb aspirator was an ordinary bulb with valve, such as are used in syringes, and a 1-foot length of small tube. The bulb was squeezed about 70 times to exhaust the original air from the bottles. It is well to test such an aspirator frequently for leakage, by ascertaining whether the squeezed bulb remains collapsed when the inlet is held closed and resists compression when full if the outlet is closed. The air may also be sucked out of the bottle by means of a rubber or other tube, by 20 or more inhalations. The bottles may be filled with water and emptied at the place of sampling, but as carbon dioxide is absorbed by water, there may be a slight loss of that gas from confining the sample in a wet bottle and from washing some of the inrushing air with the outflowing water.

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[a] For detailed discussion of the subject see Burrell, G. A., and Siebert, F. M.: The sampling and examination of mine gases and natural gas: Bull. 42, Bureau of Mines, 1913, 116 pp., 2 pls., 23 figs.

In collecting an air sample in the mines care was taken to move the bottle about near the top, bottom, and each side of a chamber, thus insuring a fair average. Where there is a strong current the air and gases are well mixed, but in places where returns join or there are local emanations of gas a carelessly taken sample may not be representative of the whole volume of air. Measurements of air currents, made at the time of collecting samples, gave the average movement of the air current in the entire cross section. They were repeated so as to eliminate local variations caused by opening and shutting doors, blocking of the shaft by cages, movement of trips of cars along gangways, and other conditions that tend to affect the air velocity.

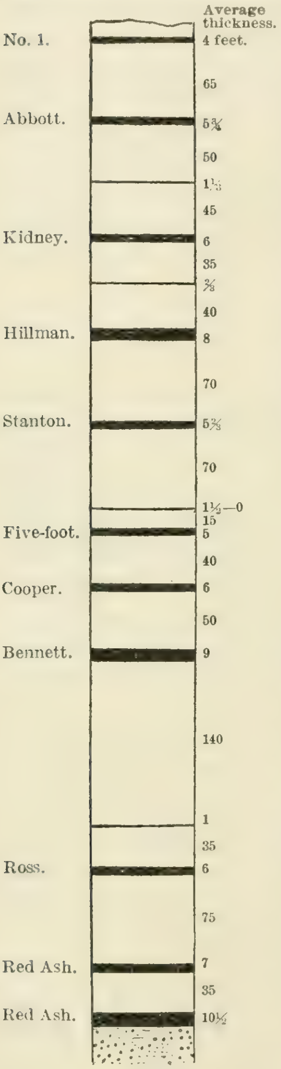

FIGURE 19.—Columnar section of coal measures at Lance mine, Plymouth, Pa.

CONDITIONS IN REPRESENTATIVE MINES.

LANCE MINE.

The Lance colliery is in the upper part of Plymouth. Its workings are largely on the north slope of the main basin, but some of them extend south across the broad syncline under the Susquehanna River. In the latter area all the principal coal beds of the region are represented, but as the north pitch is ascended some of the higher beds come to the surface. The mine is especially gaseous, the gas being derived from various beds. Although some parts of the mine are much more gaseous than others and numerous large feeders have been encountered, considerable gas is given off throughout the deeper workings.

SUCCESSION AND STRUCTURE OF BEDS.

Under the greater part of the Lance mine about the shafts and southward under the river there are 11 thick beds of coal which occur in the succession shown in figures 19. The thicknesses given are averages and there is considerable local variation. The coal beds aggregate 75 feet in thickness but only about 61 feet are coal, nearly every one of the thicker beds carrying 6 inches or more of "slate" or bone, the Bennett and Stanton beds having nearly 2 feet in parts of their areas. The general structure of the Lance mine, from the north on the mountain slope to the southern margin of the mine on the south side of the basin, is shown in figure 20. This section shows the thicker coal beds slightly exaggerated in thickness and also the thick body of river deposits covering the measures in the river flat south of the shaft. These deposits are more than 300 feet thick in places.[a]

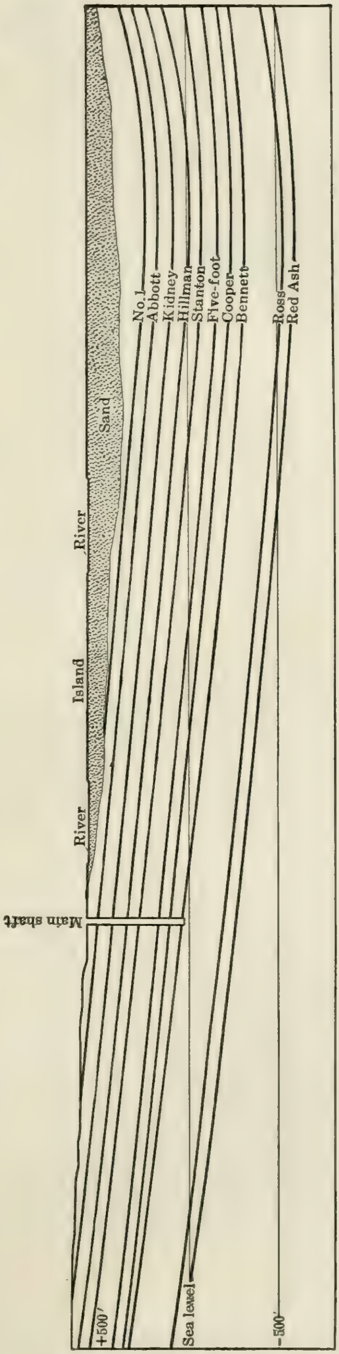

FIGURE 20.—Generalized cross section of Lance mine, Plymouth, Pa.

RETURN-AIR SAMPLES.

As the Lance mine presented varied conditions of structure, gas occurrence, depth, and surface cover, it was selected for an extended investigation. On January 7 and 9, 1911, samples of return air were taken at various points where they would be representative of certain coal beds and working areas. A year later some additional samples were taken by H. I. Smith, and the author also resampled several returns after mining had been discontinued a month. These samples were analyzed in the laboratories of the bureau at Pittsburgh, Pa., with the results given in the table following.

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[a] See Darton, N. H., Sand available for filling mine workings in the northern anthracite basin in Pennsylvania: Bull. 45, Bureau of Mines, 1913, 33 pp., 8 pls., 5 figs.

Results of analyses of return air in Lance mine.

[G. A. Burrell, analyst.]

Laboratory No.	Return.	Place of sampling.	Velocity of air current per minute.	Volume of air current per minute.	Proportion of methane in return air.	Volume of methane per minute.	Proportion of CO_2 in return air.
			Cubic ft.	*Cubic ft.*	*Per cent.*	*Cubic ft.*	*Per cent.*
1267	Bennett and overlying beds.	Total upcast, No. 1 air shaft.	....	200,000	0.96	1,920±	0.10
1271	Red ash, total	Near No. 2 air shaft	950	99,750	1.07	1,067	.17
2192	Bottom Red Ash	Just south of No. 2 air shaft.[a]	721	75,000	.99	742	.12
2197	Red Ash	400 feet from 4th east gangway.[a]	309	22,900	.65	149	.11
2195	Red Ash?	Overcast over 6th slope below 4th east gangway.[a]	347	30,700	1.59	276	.17
2209	Ross	At No. 2 air shaft[a]	593	40,900	1.13	462	.06
1270	Ross, total	No. 5 slope	873	48,888	1.46	714	.04
1265	Bennett	No. 25 tunnel	498	21,663	.32	70	.07
1275	Do	No. 2 slope	473	41,505	1.97	818	.08
1264	Do	No. 4 slope near big feeder.	377	15,080	2.39	360	.10
2171	Do	Bottom of No. 1 air shaft.[a]	452	49,300	.57	281	.04
1277	Cooper, west	In No. 11 tunnel	267	18,957	2.68	508	.13
1272	Cooper, east	In No. 23 tunnel	364	41,500	1.04	431	.06
2172	Cooper	Near No. 1 air shaft	420	44,150	1.20	529	.07
2198	Do	In No. 23 tunnel, 600 feet from No. 26 tunnel.[a]	318	23,850	.91	217	.05
2201	Do	In No. 11 tunnel west, 1 mile from No. 1 slope.[a]	364+	33,124	2.04	676	.10
1269	Five-foot, east	At No. 7 slope	390	26,220	1.46	383	.08
2213	Do	do	185	13,000	.04	5	.05
1274	Five-foot, west	do	522	28,188	.23	65	.10
2211	Do	do	441	22,100	.16	35	.08
2191	Five-foot	Near No. 2 air shaft[a]	683	34,800	.93	324	.09
1276	Hillman, east	No. 14 tunnel	402	36,984	1.50	555	.10
1273	Hillman, west	do	723	30,366	.55	167	.10
2223	Hillman and Five-foot.	Total No. 7 slope at bottom of No. 1 air shaft on Five-foot bed.[a]	1,294	49,200	.73	359	.04

[a] Collected by H. I. Smith, February, 1912.

That the Lance mine is a notable producer of methane is indicated by the fact that at No. 1 air shaft near the main hoisting shaft the methane content of the upcast air is 0.96 per cent or a volume of nearly 1,920 feet a minute, the volume of the air being about 200,000 cubic feet a minute. This air is from the Bennett, Cooper, Five-foot, Hillman, and overlying beds, from which the average daily production of coal at that time was 1,220 tons. Besides this upcast there was another fan at an air shaft 1,400 feet north which was bringing up from the Red Ash and Ross beds an additional 1,781 cubic feet of methane a minute at the time of the author's visit. The output of coal from these two beds was 710 tons a day.

RED ASH RETURNS.

The Red Ash workings in the Lance mine occupy the area shown in figure 21.

The workings north of the Susquehanna River are mostly old and most of the area being mined was under the river and islands, one gangway extending south to the bottom of the basin. There is a regular south dip throughout the worked area, the coal bed descending from near sea level in the north end of the property to 600 feet below sea level, or 1,130 feet below the surface in the bottom of the basin. There are a few local structural irregularities of small extent and, as shown in figure 19, the bed splits into two parts. The two splits are separately mined in places, the top bed being about 6 to 7 feet thick and the bottom one 7 to 11 feet thick. To the northward, where they are thinner and less rock intervenes, coal from the two splits is taken out at the same time, and the thickness of the coal and intervening rock is 20 to 23 feet. The deeper Red Ash workings have developed considerable gas in places and a 10-inch bore hole to this bed from the workings in the Stanton bed yielded a flow of gas estimated at 1,000 feet a minute. At the time of sampling the return air (sample 1271) there were 51 working faces in operation and the average daily output of coal was 643 tons. The return air from these workings has its outlet through No. 2 air shaft, near which the volume was 99,750 feet a minute. The air contained 1.07 per cent methane, or 1,067 cubic feet a minute, and was high in carbon dioxide, 0.17 per cent. If the area of coal exposed in those workings be estimated at 1,463,000 square feet, 0.73 cubic foot of methane was liberated for every 1,000 square feet of coal exposed. With 643 tons daily production the rate was nearly 2,400 cubic feet of methane per ton of coal mined.

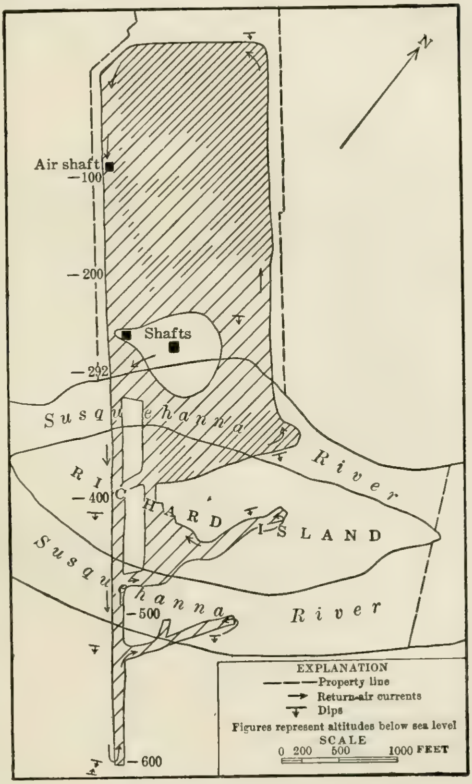


FIGURE 21.—Sketch map of worked area in Red Ash bed, Lance mine. The bed is mined in two splits in the area represented by double ruling.

ROSS RETURNS.

The Ross workings in the Lance mine, shown in figure 22, occupied very nearly the same area as the Red Ash workings but the slope to the southeast crosses the axis of the syncline and rises on the south side. Only 12 places were being worked at the time of sampling and these were all in the extreme southern part of the mine. The average daily production was 66 tons. In most breasts 5½ to 6 feet of coal was being mined. The air all went to No. 2 air shaft, which was passing 48,888 cubic feet of air a minute, the air containing 1.46 per cent methane, or 714 cubic feet a minute. Although the percentage of methane was greater than that in the air of the Red Ash returns the volume was less, but on the other hand the number of square feet of coal exposed was not quite half as much, or about 700,000, so that the 714 cubic feet of gas represents fully 1 cubic foot to every 1,000 square feet of coal exposed. The daily production was only about one-tenth as much, so the methane was at the rate of 15,600 cubic feet to every ton of coal mined.

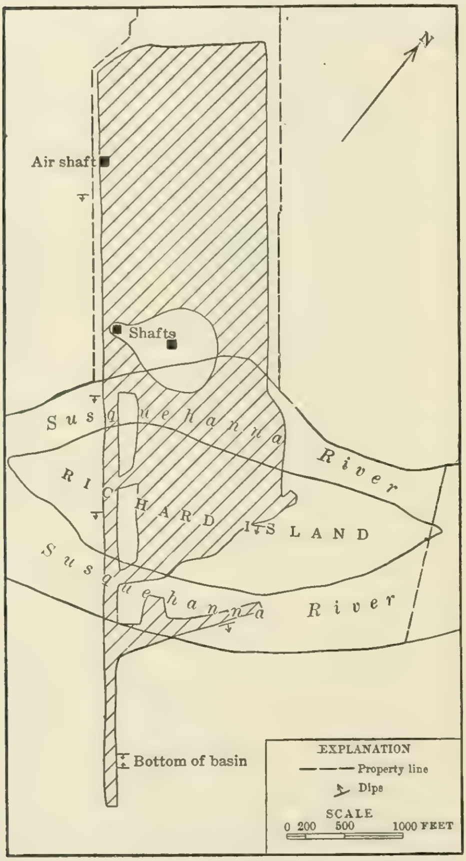


FIGURE 22.—Sketch map of worked area in Ross bed, Lance mine.

BENNETT RETURNS.

The Bennett workings in the Lance mine, shown in figure 23, occupied an area of about 500 acres. Extensive districts are not worked now and the main active workings were a mile south of the main shaft. No attempt was made to sample any considerable part of the return air from these workings but a return was selected that ventilates an area in which considerable mining was in progress. Two samples also were taken of air receiving the discharge of a large feeder at the head of the incline below a point just north of the corner of Carey Avenue and Division Street, Wilkes-Barre (see fig. 23).

The sample (Lab. No. 1265) of return air from the working area was taken at the point designated *A* in figure 23. This area is on a low anticline and occupies about 15 acres. The air current had a volume of 21,663 cubic feet a minute and carried 0.32 per cent of methane, or 70 cubic feet a minute. The average daily production was 55 tons, so that this amount of gas was at a rate of nearly 2,000 cubic feet to the ton of coal mined. The surface of coal exposed in this area was about 90,000 square feet, so that 70 cubic feet of methane indicates the escape of 0.77 cubic feet of methane per minute for every 1,000 square feet of coal exposed. Another sample (Lab. No. 1264) was taken at the point designated *B* in figure 23 near the extreme south end of the workings on No. 4 slope on the south pitch, 300 feet below a large feeder that had been active for a long time. Between this feeder and the point at which the sample was taken, however, the gas had been diluted by nearly fresh air with a volume of 15,000 feet a minute. The sample contained 2.39 per cent of methane, equivalent to 360 cubic feet a minute, practically all of which is discharged by the gas feeder. The foreman stated that at times the proportion of gas appeared to be much greater. Another sample (Lab. No. 1275) taken at the point designated *C* in figure 23 represents air from the same current sampled at *B*, but here the volume of the return was 41,505 cubic feet a minute as it included air

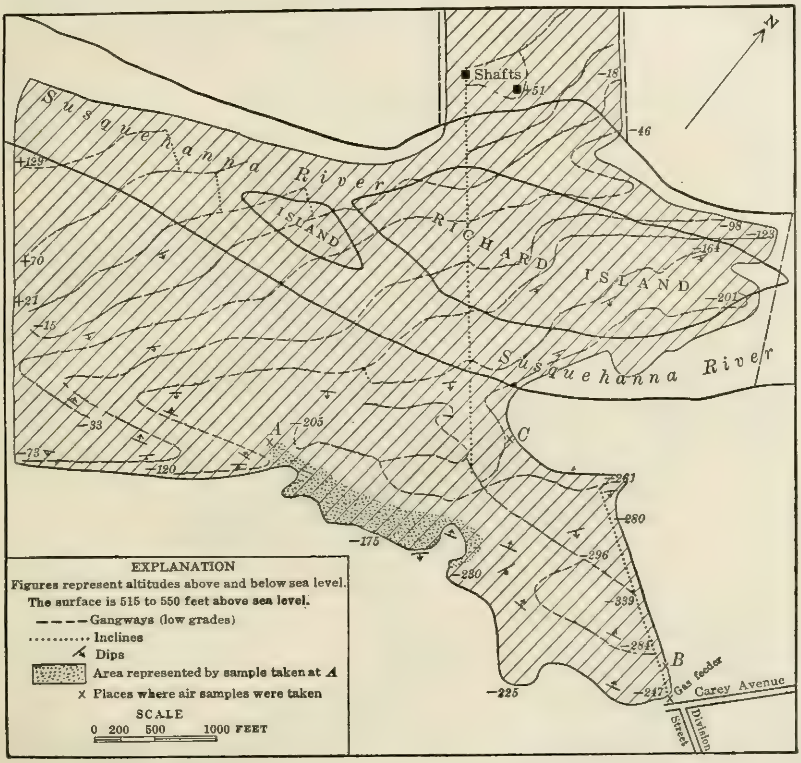


FIGURE 23.—Sketch map of worked area in Bennett bed, Lance mine.

from other returns and from a split that ventilated six nearby working faces. The methane content of this sample was 1.97 per cent, which indicated a volume of 818 cubic feet a minute, or very much more than that indicated by the sample taken at *B*.

COOPER RETURNS.

The Cooper workings at the Lance mine extend in a broad area south from the shafts under the river and flats, and one gangway reaches beyond the corner of Carey Avenue and Division Street, in Wilkes-Barre. The Cooper bed is only 50 to 60 feet above the Bennett bed, and the course of the Bennett gangways, shown in figure 24, gives an idea of the structure. There is a long descent into the central basin, and then a rise on the south side. In the central and southern part of the workings the depth below the surface is about 700 feet.

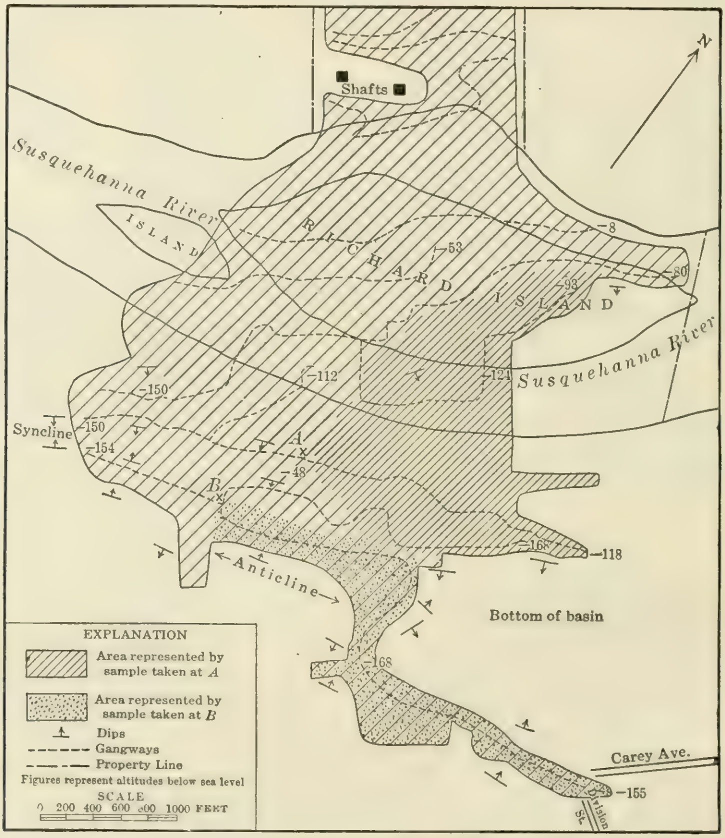


FIGURE 24.—Sketch map of worked area in Cooper bed, Lance mine.

A sample (Lab. No. 1272) of return air from the slopes and an irregular flat basin to the east was taken at the point designated *A* (fig. 24) in No. 23 tunnel, where the volume of air was 41,500 feet a minute. This air contained 1.04 per cent, equivalent to 431 cubic feet a minute, of methane. About 428,500 square feet of coal was exposed in the area ventilated by this air, so that slightly more than 1 cubic foot of gas was given off for every 1,000 square feet of coal exposed. The daily coal production in these workings averaged 193 tons, and the methane calculated to this factor gives a rate of 3,230 cubic feet to the ton.

Another sample (Lab. No. 1277) was taken at the point designated *B* (fig. 24) from the west return in the No. 11 tunnel, an air course that ventilates all the workings to the extreme south. The region presents an anticline and a syncline in which the beds are considerably disturbed. The volume of the return air was 18,957 cubic feet a minute. It carried 2.68 per cent of methane, equivalent to 508 cubic feet a minute, a remarkably large volume of gas when the small extent of the workings is considered. A precise measurement of the area of these workings was not made, but the gas emanation was equivalent to at least 5 cubic feet a minute for every 1,000 square feet of coal exposed. The average daily production from the area was 228 tons, and the volume of methane considered in this relation was at the rate of about 3,200 cubic feet to the ton of coal mined.

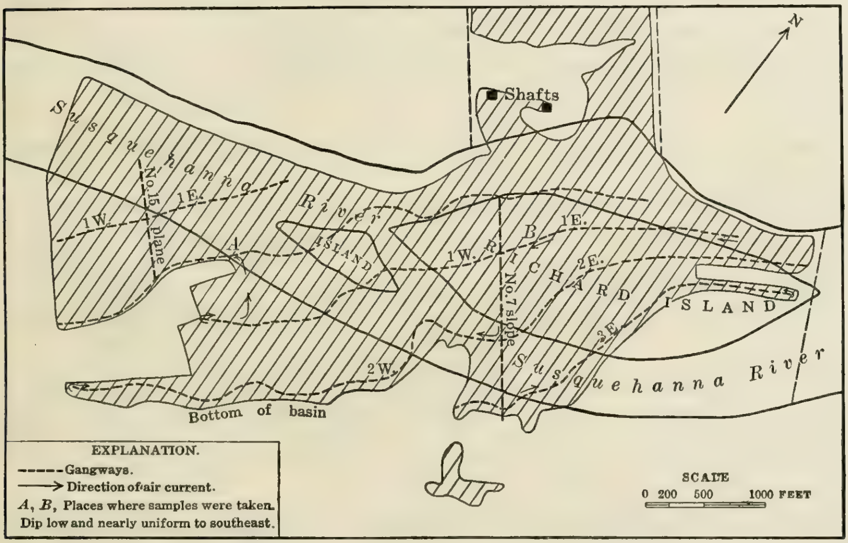


FIGURE 25.—Sketch map of worked area in Five-foot bed, Lance mine.

FIVE-FOOT RETURNS.

The Five-foot bed has been extensively developed in the Lance mine, the workings extending far under the river and beyond its south bank in places. The principal features are shown in figure 25.

The length of the workings up and down the river was 6,400 feet, and their width south of the shafts was 3,200 feet, comprising an area of about 256 acres. The dip is nearly uniform to the southeast, without noteworthy local disturbances. The bed is 5 feet thick and contains about 6 inches of shale or bone. The system of ventilation is simple. The main return air passes up No. 7 slope almost on the center line of the workings and is derived in nearly equal volumes from gangways from the west, sampled at the point designated *A*, and from the east, sampled at the point designated *B*. The sample taken at *B* did not include air in part of a gangway on the east side, from which a few old chambers had been turned off. The extent of the workings on the two sides was about equal at the time of the author's visit, there being 14 working faces on the west side and 11 on the east side, all of which extended under the river at a uniform depth below the surface. The results of the tests and their relations to various factors are given in the following table:

Results of comparative sampling of air in east and west returns in Five-foot workings, Lance mine.

Source of sample.	Side.	Working places.	Tons per day.	Coal exposed.	Air volume.	Methane.			
						Per cent.	Volume.	To 1,000 square feet of coal exposed.	Per ton.
				Sq. feet.	*Cu. feet.*		*Cu. feet.*	*Cu. feet.*	*Cu. feet.*
Point B [a]	East	11	89	300,000	26,900	1.46	400	1.67	6,400
Point A [a]	West	14	167	240,000	28,000	.23	70	.23	60

[a] See fig. 25.

The most notable feature in this table is the great preponderance of methane from the east side, whether calculated to volume, tonnage, or square feet of coal exposed, and the amount of coal mined is only about half as much as on the west side. This excess of gas was not derived from feeders, but appeared to come from coal of the same character and under similar conditions as that on the west side workings.

HILLMAN RETURNS.

The workings in the Hillman bed in the Lance mine, shown in figure 18, are mostly under the river and the flat just south of the river. The measure dips south into the main syncline, but the Hillman workings are all on the north dip. The thickness of the coal bed is 7½ to 8 feet. The return ventilation is from east and west workings through "east" and "west" gangways, emptying into a central outlet. The area of the workings on the east side is about 25 per cent greater than those on the west side.

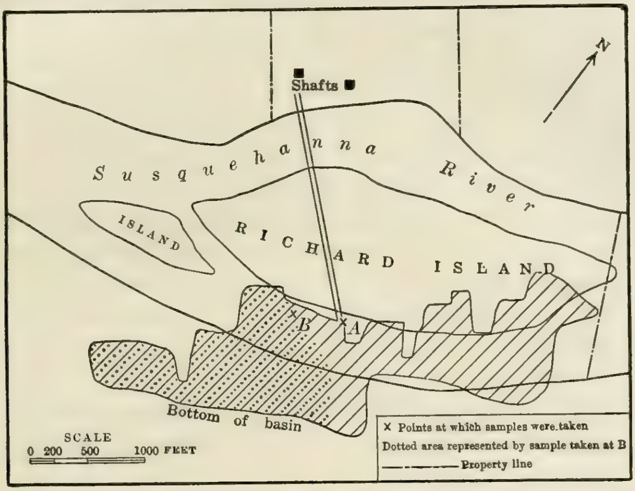


FIGURE 26.—Sketch map of worked area in Hillman bed, Lance mine.

The air was sampled at points designated *A* and *B* in figure 26, in the last returns entering on either side of No. 14 tunnel, with results as follows:

Results of comparative sampling of air in east and west returns in Hillman workings, Lance mine.

Source of sample.	Side.	Working places.	Tons per day.	Coal exposed.	Air volume.	Methane.			
						Per cent.	Volume.	To 1,000 square feet of coal exposed.	Per ton.
				Sq. feet.	*Cu. feet.*		*Cu. feet.*	*Cu. feet.*	*Cu. feet.*
Point A [a]......	East....	21	208	242,000	36,800	1.50	552	2.3	3,850
Point B [a]......	West....	14	116	192,000	30,366	.55	167	.9	2,070

[a] See fig. 26.

The structural conditions on the east and west workings are similar to each other and to those in the Five-foot workings 160 feet below. On the east side the volume of methane is three times that on the west side, whereas the number of working faces is only 50 per cent more and the average daily production is somewhat less than twice as much.

RÉSUMÉ OF CONDITIONS IN LANCE MINE.

The results given on the preceding pages show that in the Lance mine gas occurs under greatly differing conditions. The outflow of methane from the different districts in the same bed under the same structural conditions varies widely. The greatest amount of gas is in the region south of the shaft under the river and the river flats where the coal beds lie farthest below the surface.

METHANE OUTFLOW FROM HILLMAN AND FIVE-FOOT BEDS.

The Hillman bed is reputed to yield the most gas and this reputation appears just. The return from its east workings, which are of relatively small extent, was found to carry 555 cubic feet of methane a minute, whereas the west return, ventilating a closely similar district, carried only 167. This same difference between the east and west workings is shown in the Five-foot bed not far below, where the east return carried 400 cubic feet of methane a minute and the west return only 70. This difference is seemingly not due to the structure, for the dips are about the same on both sides, nor to the porosity of the overlying beds, which could not account for such a great difference from east to west and between the two beds. Unfortunately it was not practicable to continue this comparison to lower beds, for the fresh workings in the lower beds were not apportioned in the same manner.

OUTFLOW FROM COOPER AND BENNETT BEDS.

The Cooper workings represented by the two samples taken (Lab. Nos. 1272, 1277) lie mostly south and east of the east workings of the Five-foot and Hillman beds. It is stated, however, that the Cooper workings to the west and north were much less gaseous than those to the east and south. The sample taken at *B* (fig. 24) of air from the southernmost workings carried a very high proportion of methane (2.68 per cent), equivalent to 508 cubic feet a minute, whereas the return air from the much more extensive workings in the broad undulating district to the north carried only 1.04 per cent, or 431 cubic feet a minute, which, considering the extent of coal exposed, is not more than one-quarter as much to the square foot of coal. It is stated that the proximity of a fault or break in the beds far to the south is the source of the increased yield of gas and also of the large feeder in the Bennett bed, about 80 feet below. This feeder is of great volume, as shown by the sample (Lab. No. 1264) taken at *B* (fig. 24) in No. 4 Bennett slope, in an air current of 15,000 feet a minute, which contained 2.39 per cent methane, or 360 cubic feet a minute, which was nearly all from the feeder. Air (sample 1265) from a typical working area of Bennett coal taken at *A* (fig. 23), near the bottom of the basin, carried only 0.32 per cent methane, or 70 cubic feet a minute, a volume nearly equivalent to that from the west workings of the Hillman bed that are about twice as extensive. A sample (Lab. No. 1275) of return air taken at *C* (fig. 23) in the bottom of the basin showed a very large volume of methane, which came in part from the large feeder mentioned above and in part from a gaseous district where a small amount of coal was being mined.

The total volume of methane delivered by the Five-foot upcast, however, was not far from 500 cubic feet a minute, and the amount from the Hillman bed is very close to the sum of the volumes passing at *A* and *B* (fig. 26), which is 722 cubic feet a minute. The content of methane in the air from the main upcast at the mouth of shaft No. 1 was 0.96 per cent, but the volume of this air was not measured. Assuming that it was 200,000 feet, the volume of methane was 1,920 feet a minute, but after the volumes of methane from the Five-foot and Hillman beds are deducted from this figure there remain only 713 cubic feet a minute for the total methane of the Bennett and Cooper returns. This is far too little, as in the No. 2 Bennett slope the volume was 818 cubic feet. However, if the volume of the upcast current be taken as 250,000 feet, the volume of methane becomes 2,400 feet, leaving 1,200 feet for the Bennett and Cooper returns.

OUTFLOW FROM ROSS AND RED ASH BEDS.

The amount of methane coming from the Ross and Red Ash workings was nearly the same, the Ross return showing the larger percentage, but the Red Ash return carrying the larger volume of the gas on account of the greater volume of air, 1,067 cubic feet a minute. Offsetting this in some measure is the fact that the area of coal surface exposed in the thick Red Ash bed was much greater than in the Ross bed, so that the emanation to the square foot of coal exposed was really less in the Red Ash than in the Ross bed. On the other hand, the daily production from the Red Ash bed was nearly ten times as much as was being mined from the Ross workings, so that in the latter there was more than six times as much gas to the ton mined. The samples were taken so near the upcast in both beds that they represented the total gas from each. The extent of the workings was nearly the same in both beds and the structural and other conditions are similar.

GENERALIZATIONS AS TO METHANE EMANATIONS.

In general the amount of gas emanating from the workings of the Lance mine varies greatly in different parts of the various beds, and the local variations in the same bed are not related to structure or to cover. Considerable gas comes directly from feeders or blowers of greater or less size and duration, some of which produce more gas than the regular emanation from a large coal area. Gas also enters some of the workings from the sandstone floor or roof. One notable zone of feeders was developed in a tunnel in which the gas came from a lower split of the Stanton bed through an 8-foot bed of sandstone separating the two splits. The large feeder in the south workings in the Bennett bed was emitting 360 cubic feet of methane a minute at the time of the author's visit. If the relative extent of workings be considered, the Hillman bed is the most gaseous except a small area of the Cooper workings. The following table gives some estimates of the number of cubic feet of methane per minute per 1,000 square feet of coal exposed in different parts of different beds.

Volume of methane per 1,000 square feet of coal exposed in different parts of different beds, Lance mine.

Bed.	Part of return.	Volume of methane per minute.
		Cubic feet.
Red Ash	Total return	0.73
Ross	do	1.00
Bennett	South basin	.77
Cooper	Central east	1.00
Do	Southernmost	5.00±
Five-foot	East side	1.67
Do	West side	.23
Hillman	East side	1.00
Do	West side	2.30

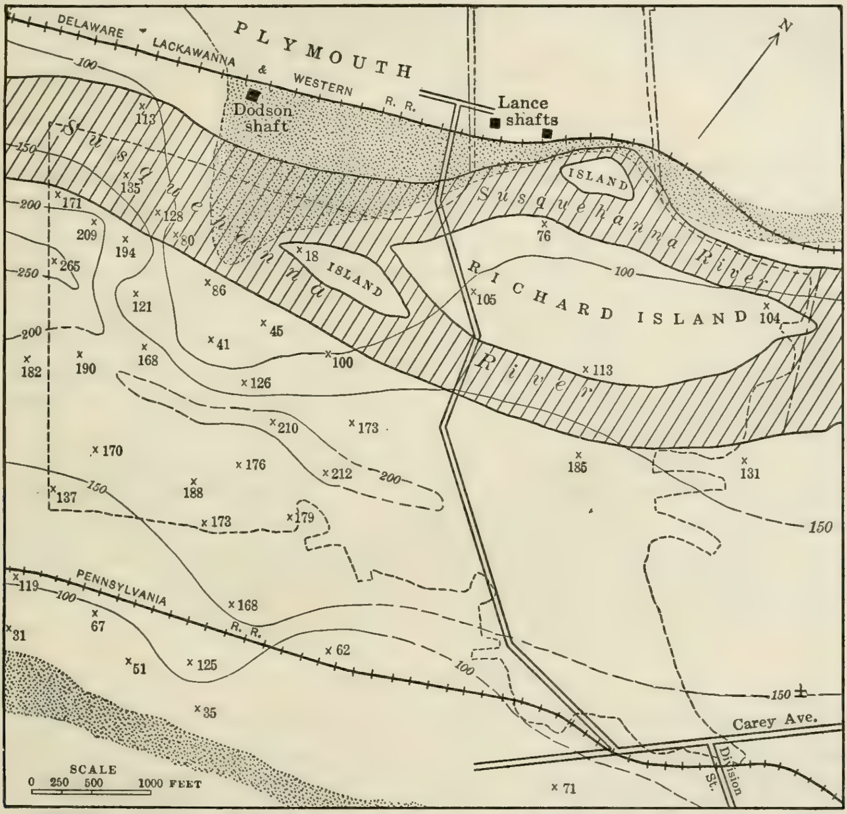
In reading these figures one should consider that the amount of gas from working faces is much greater than from old pillars and gangways, the relative extent of which was not ascertained. The relation of methane emanation to amount of coal mined gives some interesting figures, but their significance is greatly diminished by the fact that after the mine had been shut down nearly a month in April, 1912, the volume of gas had not greatly diminished in any of the workings, and in some it was the same or greater. The figures in the following table show the relation of volume of methane to average daily output in January, 1911:

Volume of methane per ton of coal mined at Lance mine.

Bed.	Part of return.	Average daily production.	Volume of methane.	
			Per minute.	Per ton mined, approximate.
		Tons.	*Cubic feet.*	*Cubic feet.*
Red Ash	Total return	643	1,067	2,400
Ross	do	66	714	15,600
Bennett	South basin (No. 25 tunnel).	55	70	2,000
Cooper	Central east (No. 23 tunnel).	193	431	3,230
Do	Southernmost (No. 11 tunnel).	228	508	3,200
Five-foot	East side	89	400	6,400
Do	West side	167	70	60
Hillman	East side	208	552	3,850
Do	West side	116	167	2,070
All beds	Two shafts	1,930	3,701	2,761
Red Ash and Ross	North shaft	709	1,781	3,617
All except Red Ash and Ross beds	South shaft	1,221	1,920	2,264

INFLUENCE OF RIVER DEPOSITS.

As most of the Lance workings south of the shaft lie below river deposits of varying thickness, it appeared possible that these might affect the occurrence of gas in the beds below. Part of the deposits are thick and contain considerable clay which would tend to retard the general outflow of gas from the coal. Special attention was given to this feature, and as there were many bore holes the extent and thickness of the valley filling could be ascertained. The principal data bearing on this are given in figure 27.



▨ Rock at or near surface. x Figures show bore holes, with depth to rock. ------ Margin of Lance workings
Irregular solid and broken lines show thickness of valley filling, vertical intervals 50 feet.

FIGURE 27.—Sketch map showing thickness of valley filling, Lance mine.

This map shows a deep central channel with the rock rising to or near to the surface on either side. At the deepest place the filling is more than 250 feet thick, and there is a wide area in which it is more than 150 feet thick. Although sand and gravel are the principal materials, there is enough clay to affect permeability decidedly. A promontory of rock southwest of the Lance shafts is a notable feature and the sandstone which comes to the surface must be the avenue of escape for considerable gas. It is a fact that the most gaseous parts of the Lance workings are under the center of the channel southeast of Richard Island; but, on the other hand, the less gaseous parts of the present Five-foot, Hillman, Cooper, and Bennett workings are under an equally thick valley filling. It is stated that the workings of the higher beds in the vicinity of the rock promontory above mentioned were not especially gaseous, but not materially less so than in some districts more deeply covered by the valley filling. There are in the coal measures thick beds of fire clay that appear to be just as impervious as the clay in the valley fillings, and no doubt these are a most important factor in impeding the escape of gas to the surface.

SOUTH WILKES-BARRE MINE.

In Mine No. 5 of the Lehigh & Wilkes-Barre Coal Co. a series of return-air samples was collected to ascertain the relation of certain structural features to the occurrence of methane. The coal measures are here flexed into anticlines and synclines of moderate steepness, most of the dips being from 5° to 45°. There are, however, several local rolls or so-called "faults" in which the dips are steeper. The principal beds worked are the Baltimore, Hillman, Abbott, and Kidney. Owing to the folding, the depths of the beds vary greatly, some of the Hillman workings in the northern part of the mine being more than 1,100 feet below the surface. There is considerable gas throughout the mine, but its volume and manifestations have varied greatly from time to time. The Hillman bed was producing the most gas at the time of sampling, but it was stated that the Baltimore bed, which was not being worked so extensively as formerly, had many very gaseous places and occasional transient blowers.

RETURN-AIR SAMPLES.

In taking samples of return air in this mine the Abbott and Hillman workings were selected because these beds were especially gaseous and the system of ventilation was such that representative samples could be obtained readily. Moreover, the workings extended through areas presenting considerable variation in structure. The samples were analyzed, with the following results.

Results of analyses of samples of return air from Abbott, Hillman, and Stanton workings, South Wilkes-Barre mine.

[G. A. Burrell, analyst.]

Lab. No.	Return.	Place of sampling.	Location on map.	Volume of air per minute.	Velocity of air per minute.	Proportion of methane in mine air.	Volume of methane per minute.
				Cubic feet.	*Feet.*	*Per cent.*	*Cubic feet.*
1209	Abbott................	No. 7 slope, 300 feet south of No. 5 shaft.	A	20,160	240	1.14	230
1208	.....do.............	No. 4 tunnel outlet, 80 feet north of No. 5 shaft; station 1244.	B	44,676	438	.44	197
1218	.....do.................	No. 4 tunnel outlet, 80 feet north of No. 5 shaft; station 1244, 2d outlet.	C	72,420	710	.42	304
1214	Abbott, east...........	Return from No. 17 tunnel.	D	[a] 21,175	605	.32	68
1216	.....do.................	Return from No. 11 tunnel.	E	[b] 17,550	585	.18	32
1215	Hillman and Stanton, west.	Outlet of No. 4 tunnel near station 105.	F	30,240	210	1.43	432
1213	.....do.................	No. 4 tunnel, east of station 866.	G	[c] 18,450	246	.67	124
1217	Stanton and Hillman..	No. 4 tunnel; station 853.	H	33,264	336	.95	316
1266	Total upcast of all beds.	Fan No. 1................	....	315,000	1,226	.72	2,269

[a] Nearly fresh air from No. 3 shaft and Hillman and Kidney gangways; entered Abbott workings through No. 17 tunnel, at the end of which it was split, and ventilated 7 working faces.

[b] Air entered at No. 3 shaft, passed along Kidney and Hillman gangways, then up plane and along No. 11 tunnel into Abbott workings.

[c] Air passed from No. 3 shaft down No. 4 tunnel, and through 9 working faces at 70 feet below sea level.

The total volume of upcast air of the South Wilkes-Barre mine was sampled at fan No. 1, on shaft No. 5, where it was approximately 315,082 cubic feet a minute. The methane content was 0.72 per cent, or 2,269 cubic feet a minute. This sample represents air from all the workings in the Baltimore and in the higher beds.

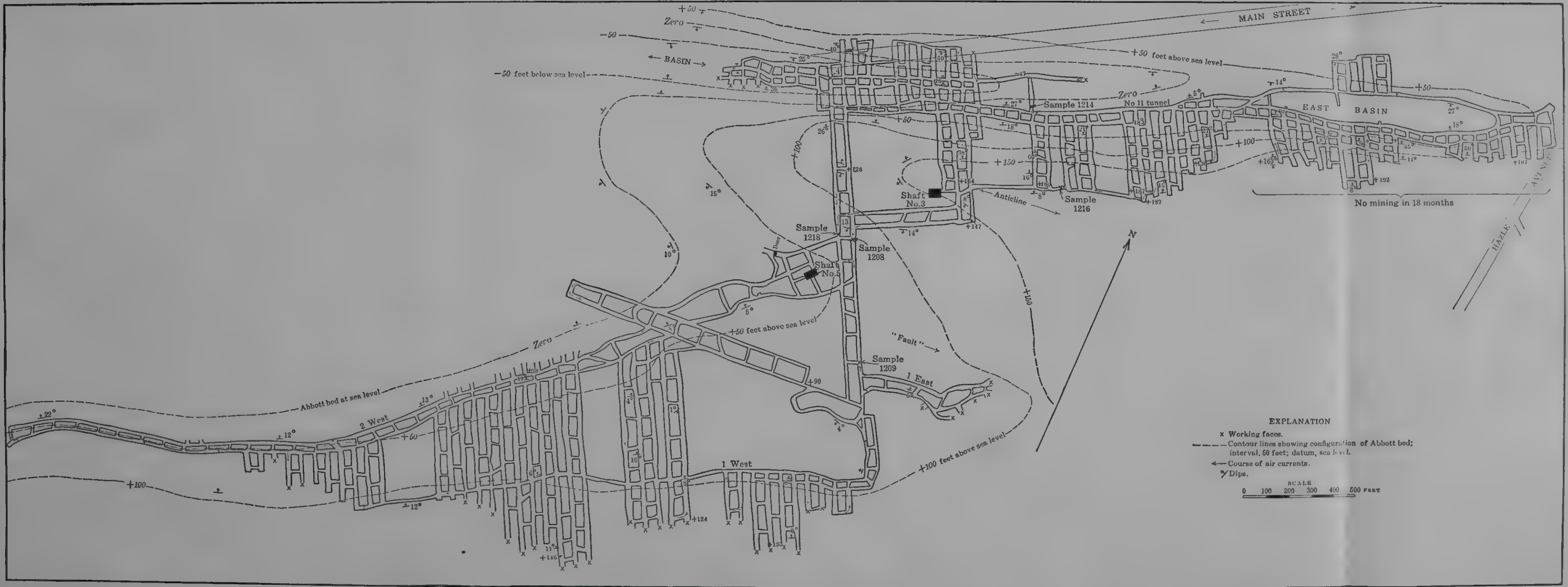
AIR SAMPLES FROM THE ABBOTT RETURNS.

The Abbott workings at the South Wilkes-Barre mine are mostly east, north, and south of the shafts. The north workings are in a long, deep basin, in part of which the measures extend somewhat below sea level, or 500 to 600 feet below the surface. The length of the workings in this basin was about 3,600 feet along an east and west line, the easternmost chambers being at Hazel Avenue, a short distance south of Main Street, Wilkes-Barre. The dips in this basin are mostly 6° to 40°, many of them being more than 15°. The surface is covered by a thin body of sand and gravel deposited by the river.

The south workings are in strata which rise gently to the southward, and are about 500 feet below the surface, or 30 to 145 feet above sea level. The surface is hilly and mostly rocky, with a scattered covering of glacial till. The south workings had been extended to a point about 3,600 feet southwest of shaft No. 5. In the Abbott workings the strata are not broken by true faults, but there are many local rolls in the beds, and in places considerable crushing and shattering, especially in the steeper slopes into the north basin. In general the workings are gaseous, especially in the breasts where coal is freshly exposed. The average thickness of the coal bed is about 6 feet.

The return air from the Abbott workings was sampled at several places so as to compare the amount of methane given off in various districts where depth or structural conditions differ. The air enters at shaft No. 3 and shaft No. 5; the intake from No. 3 entered by airways from other beds and was distributed through tunnels. The principal features are shown in Plate III. Sample 1209 was taken from the return from the extensive southwest workings in the Abbott coal, in all of which the dip of the beds is north at angles, mostly between 10° and 30°, with local variations. The air enters by the No. 5 shaft and at the place where sample 1209 was taken, 300 feet from the shaft upcast, it had a volume of 20,160 cubic feet a minute. As shown in Plate III, 31 faces were being worked, all of them up the dip. The return carried 1.14 per cent methane, or 230 cubic feet a minute. The length of the workings being about 58,600 feet and the height about 6 feet, there was about 351,600 square feet of coal exposed. Therefore 0.65 cubic foot of methane a minute was given off for every 1,000 square feet of coal surface. The average daily output from these workings was 410 tons, so that the methane was at the rate of 808 cubic feet to the ton of coal, a low rate as compared with the amount in most of the Lance workings.

Samples 1208 and 1218 were taken in two airways just north of shaft No. 5, or the main upcast; the samples represented the return air from all the north workings in the Abbott bed. These workings are in the deep, closely compressed basin north of the shafts and extending east as far as Hazel Avenue, Wilkes-Barre. The beds dip into the basin at angles of 8° to 60° and in places are considerably crushed. There were only a few breasts being worked at the time, and these were at the points shown in Plate III. The air enters the mine at No. 3 shaft; part of it goes directly to the Abbott workings and part indirectly through gangways and tunnels in other beds. The volume of the return air of the two airways at the time of sampling was 117,096 cubic feet a minute. The proportion of methane was 0.42 per cent in one airway and 0.44 per cent in the other, indicating a total volume of 501 cubic feet of methane a minute. The length of coal exposed in passageways and chambers in the Abbott workings ventilated by this air was 46,000 feet and as the average height is 6 feet the total area of coal exposed was 276,000 square feet. A calculation from these figures gives 1.8 cubic feet of methane a minute for each 1,000 square feet of coal exposed.



MAP OF PART OF WORKINGS IN ABBOTT BED, SOUTH WILKES-BARRE MINE, PA.

The air represented by sample 1214 entered the mine at the No. 3 shaft, passed along some Hillman and Kidney gangways and then through No. 17 tunnel to the point designated "A" in Plate III, where it was split to ventilate seven working faces in the deep basin lying north of the shaft. These workings extend east for about 1,300 feet to the point where the sample was taken, and were only moderately gaseous. The air current measured 21,175 cubic feet a minute and contained 0.32 per cent methane, or 68 cubic feet a minute. As about 66,000 square feet was exposed in the workings ventilated, slightly more than 1 cubic foot of methane to 1,000 square feet of coal is indicated.

A sample of this air taken by H. I. Smith in February, 1912, in No. 17 tunnel east of station 866 contained 0.89 per cent of methane. The air volume was 6,200 feet and its methane content was 51 cubic feet a minute.

Sample 1216 was taken in the east Abbott return, 500 feet east of shaft No. 3. This return carried the air from the basin extending for nearly a half mile east to Hazel Avenue, in which no active mining had been done for a year and a half. The air current had a volume of 17,550 cubic feet a minute and contained only 0.18 per cent of methane, equivalent to 32 cubic feet a minute. About 141,000 square feet of coal was exposed, so that the outflow of methane per 1,000 square feet of coal exposed was only 0.227 cubic foot per minute.

AIR SAMPLES FROM THE HILLMAN RETURNS.

The Hillman workings in the northern part of the South Wilkes-Barre mine yield so much gas that at times mining operations have had to be discontinued. The workings are mainly in two deep basins, the northern one extending to 625 feet below the surface (90 feet below sea level) and the southern one to 850 feet below the surface (more than 300 feet below sea level). An anticline 500 feet or more high separates the basins, and there is another anticline at shaft No. 3 on the south side of the south basin. The relations and the extent of the workings (in November, 1911) are shown in Plate IV, which also bears contour lines and dip marks showing the structure. The area was ventilated by air from the downcast at shaft No. 3, which passed along an airway a short distance and then through the long No. 4 tunnel. Samples 1215 and 1216 represent the total return air from the northern basin, whereas sample 1217 mainly represents air from the workings on part of the north slope of the south basin. Sample 1215 was taken in one of the main returns; this air contained 1.43 per cent methane, equivalent to 432 cubic feet a minute. Sample 1213 was taken in an airway in the north basin from another return, which ventilated nine working faces. The return air contained 0.67 per cent of methane, 124 cubic feet a minute, which, added to the amount at the place where sample 1215 was taken, makes 556 cubic feet for the total volume from the northernmost workings.

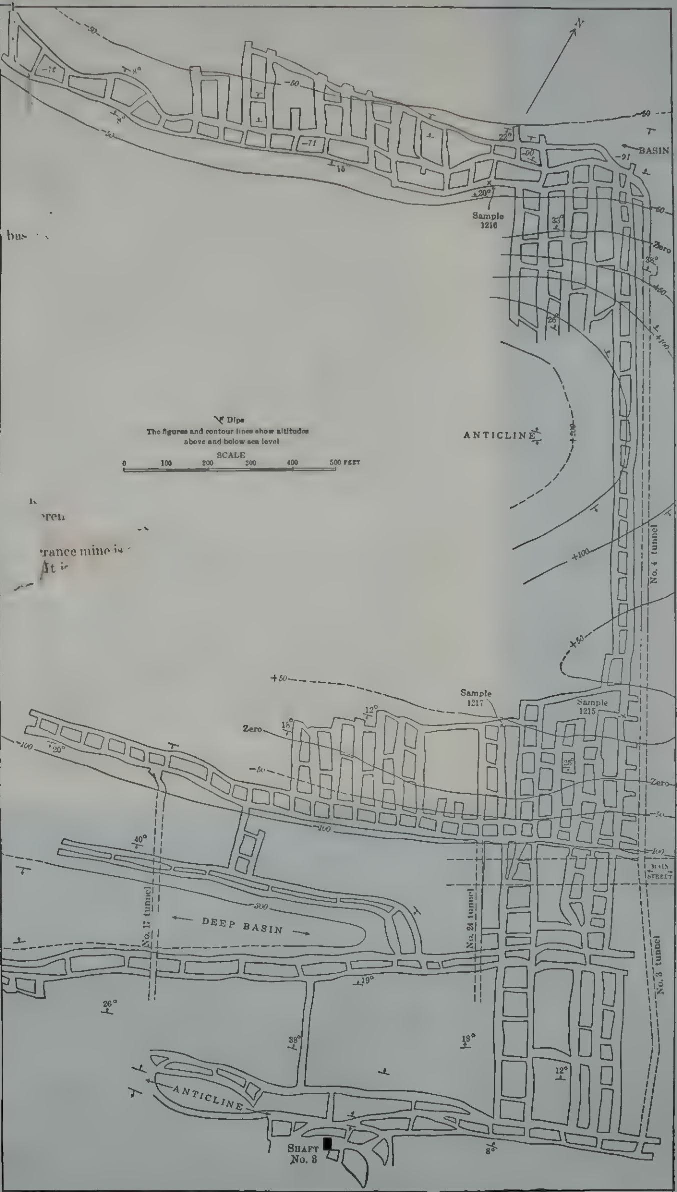
If the length of coal face in these workings, about 14,500 feet, is multiplied by the thickness of the bed, 7 to 8 feet, the number of square feet of coal exposed becomes 108,700. Five hundred and fifty-six cubic feet of gas a minute from this area is at the rate of slightly more than 5 cubic feet for each 1,000 square feet of coal surface. Of course the rate of emanation varies greatly and is much more in the fresh working faces than in pillars and old chambers. The average daily coal production from this district was 94 tons, so that the methane emanation calculated to this tonnage is 8,534 cubic feet to the ton.

Sample 1217 represented a decidedly gaseous area in the Hillman workings lying a short distance north of shaft No. 3 and about 500 to 650 feet underground. The strata dip 15° to 30° south into a deep basin. The air passed from No. 3 shaft along the Hillman airway through No. 3 and No. 4 tunnels and about 800 to 1,000 feet of gangways, being diluted somewhat by air from a small area of workings in the Stanton bed where two places were being worked. No work was being done in this Hillman area. The length of faces in it was about 9,000 feet and their average height 7 to 8 feet, so that the coal surface exposed was about 67,500 square feet. The outflow of gas from this area being 316 cubic feet a minute and 250 feet of this being assumed to come from the Hillman workings, the volume given off for every 1,000 square feet of coal exposed was 3.7 cubic feet a minute, or decidedly less than in the basin represented by samples 1215 and 1213. A sample of this air, taken early in April, 1912, carried 2.25 per cent of methane, and another sample, taken in No. 4 tunnel, 2.36 per cent.

The mine foreman stated that the Hillman bed appeared to be as gaseous where undisturbed as in or near slips or breaks or along anticlinal and synclinal axes. The very gaseous places in the north workings are along the two sides of a low anticline. A sample of gas from a cavity in the roof over a fall in the No. 5 slope was found to carry 93.88 per cent methane, 0.25 per cent carbon dioxide, 2.17 per cent oxygen, and 3.70 per cent nitrogen.

RÉSUMÉ OF CONDITIONS IN SOUTH WILKES-BARRE MINE.

In this mine the most gaseous district, the north Hillman workings, was producing 556 cubic feet of methane a minute, or more than 5 cubic feet a minute for every 1,000 square feet of coal exposed. The return from the Hillman workings in the basin near the shaft (Lab. No. 1217) carried nearly 1 per cent methane, representing a



MAP OF NORTH WORKINGS IN HILLMAN BED, SOUTH WILKES-BARRE MINE, PA.

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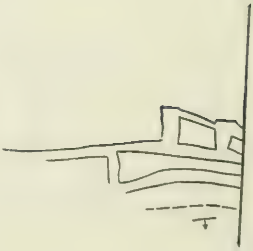


of 3.7 cubic feet a minute for every 1,000 square feet of coal.
fference in the amount of methane produced in these two
night be entirely due to the active mining in the north basin,
ording to the testimony of the mine foreman this was not the
Neither could the variation have been due to differences in
gic structure or to the thickness and tightness of cover, for
too nearly alike in both areas.

much less gas in the Abbott bed 220 feet above the Hill-
ugh both coals are regarded as of the same general class
early the same thickness. In the basin over the one repre-
sample No. 1217 the methane emanation (see Lab. No.
nly 0.32 per cent, or 1 cubic foot a minute to every 1,000
of exposed coal, less than one-third as much as in the
ings. Similarly, the return air (sample 1216) from the
ings, east of the shaft, and on the eastern extension of the
me basin n which sample 1214 was taken, carried only 0.18 per cent methane, or only 0.23 cubic feet a minute for every 1,000 square feet of coal surface. The difference in the amount of gas at the two places is believed to be due to the fact that the air from which sample 1214 was taken ventilated active working faces (seven), whereas the area represented by sample 1216 had not been worked for some time.

The Hillman workings southwest of the shaft were not especially gaseous as a whole, and the air, which was not sampled, probably carried much less gas than that from the north workings represented by samples 1215, 1213, and 1217. The Abbott workings in the area southwest of the shaft gave off twice as much gas as those to the north. This is shown by the methane content of sample 1209, from a return of nearly the same volume as the one represented by sample 1214, but the former carried 1.14 per cent methane, or 0.65 cubic feet
minute for every 1,000 square feet of coal surface. However, in
s district there were 31 working faces, as against 7 in the district
which sample 1214 was collected, which may account for part
difference.

RRANCE MINE.

Dorrance is one of the newer collieries of the Lehigh Valley
Co. It is situated in the northern edge of Wilkes-Barre, and its
kings extend north under the Susquehanna River and the flats beyond nearly to Kingston Corners. It has been an exceptionally gaseous mine, and parts of it have had to be operated with special care on that account. Considerable attention was given to this mine because of the varied conditions that could be investigated. The workings show diversity of geologic structure, there being a general deep syncline north of the river and several subordinate undulations. The gaseous areas were irregular in extent, and much gas was being or had been derived from "blowers." The Hillman workings have had

the most noticeable gas manifestations, but the analyses of return air demonstrated that the smaller Five-foot workings produced somewhat more gas for each square foot of coal exposed.

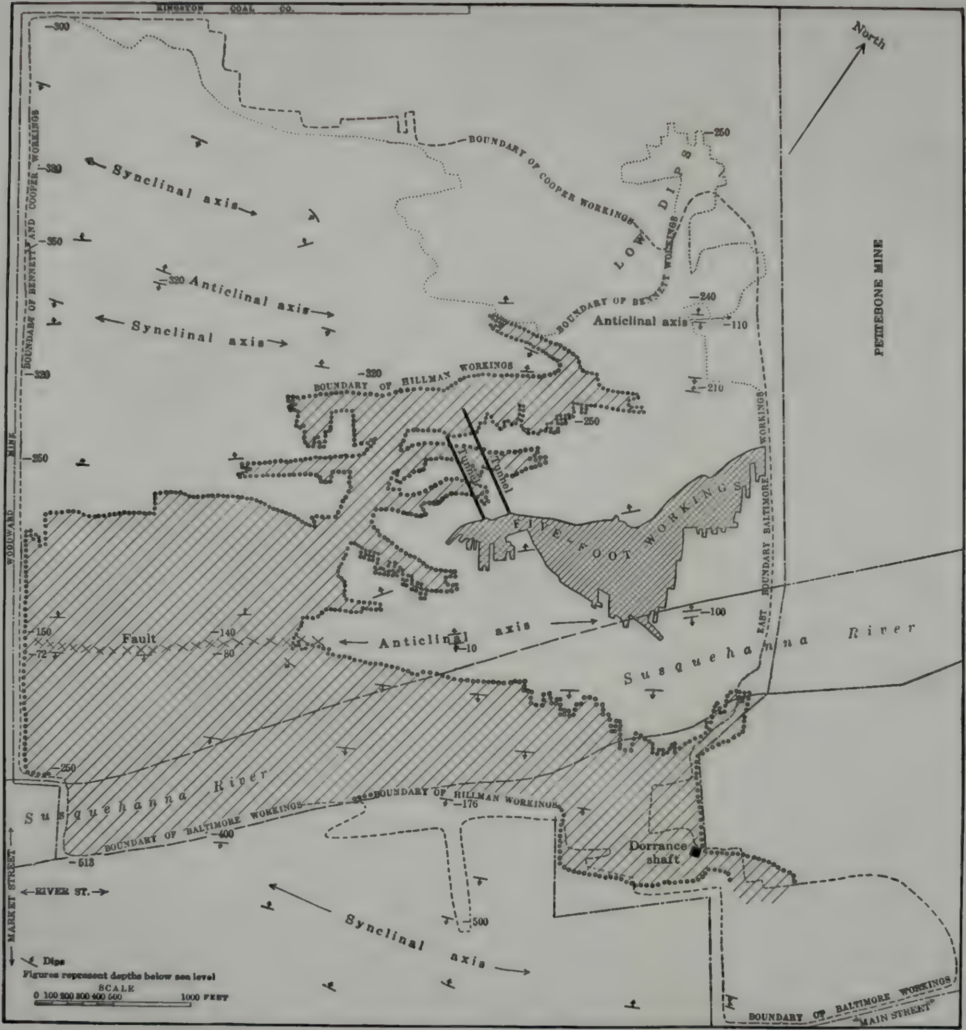
SUCCESSION AND STRUCTURE OF BEDS.

The area being mined at Dorrance included two deep synclines containing about 1,000 feet of strata and all the coal beds represented in the northern basin, their aggregate thickness being more than 75 feet (see fig. 18). At the base is the Red Ash bed, which attains a thickness of 14 feet over a wide area. The two Ross beds, 3 to 4 feet thick, are nearly 100 feet higher, and the Baltimore bed is 250 to 400 feet above the Red Ash bed. The Baltimore bed, which averages 14 feet in thickness, splits into two beds, the Cooper and the Bennett, not far north of the Susquehanna River. These beds finally become separated by a thick wedge of sandstone near Wyoming Avenue, in Dorranceton. The Five-foot bed lies 200 feet above the Baltimore (Cooper), and the Hillman, 6 feet thick, is 350 feet above. In the next 150 feet are the Bowkley and Abbott (Snake Island) beds, each about 5 feet thick, and there are other thinner coal beds still higher up. The surface north of the Susquehanna is a wide river flat, mantled with about 100 feet of sand, gravel, and clay. The proportion of clay is sufficient to constitute a moderately impervious capping competent to impede the escape of gas, though at certain points considerable gas escapes to the surface.

The structure in the Dorrance mine area is shown in Plate V by dip marks, axial lines, and elevations on the Baltimore coal bed. In general, the workings are in the deep central part of the main syncline of the basin. There are several minor folds within this basin which have axes essentially parallel to the axis of the main trough. One of these is an anticline extending across the worked area with its axis under the north bank of the river and developing into a fault to the west. The strata and its southern side descend about 500 feet into a deep syncline that passes south of the Dorrance shaft. The north slope of the anticline descends into a broad basin 100 to 200 feet deep, separated into two synclines by a long, narrow anticline that in part is faulted near its crest. This anticline is the so-called "fault" that crosses the Pettebone workings to the east.

RETURN-AIR SAMPLES.

The main returns of the Dorrance mine were sampled in December, 1910, and some of them were sampled again in the following month. Additional samples were collected by H. I. Smith early in April, 1912. The analyses of these samples are given in the table following. Analyses of samples taken by the author late in April, 1912, after mining had been suspended for nearly a month, are given on page 144.



MAP OF BALTIMORE, FIVE-FOOT, AND HILLMAN WORKINGS IN DORRANCE MINE, PA.

Analyses of return air in Dorrance mine.

[G. A. Burrell, analyst.]

Lab. No.	Date.	Return.	Place of sampling.	Air current.		Methane.		CO₂.
				Velocity per minute.	Volume per minute.	Proportion in mine air.	Volume per minute.	
				Cu. ft.	*Cu. ft.*	*Per ct.*	*Cu. ft.*	*P. ct.*
1219	Dec. 16, 1910	Red Ash	Rock slope to Baltimore.	865	87,500	0.99	868	......
1298	Jan. 25, 1911	do	do	709	95,715	1.07	1,024	0.09
2531	Apr. —, 1912	do	do	647	78,900	1.37	1,080	.10
1300	Jan. 25, 1911	Baltimore-Red Ash - Five-foot.	Foot of Baltimore shaft, north side.	1,428	197,540	.49	968	.08
2534	Apr. —, 191-	do	do	1,110	139,900	1.02	1,427	.45
1299	Jan. 25, 191	do	Foot of Baltimore shaft, south side.	1,428	101,844	.64	652	.10
2533	Apr. —, 1911	do	do	1,300	159,000	.73	1,161	.06
1221	Dec. 16, 1910	Five-foot	On plane to Baltimore.	190	13,870	1.38	191	......
2541	Apr. —, 1912	do	do	153	18,700	.84	157	.31
1212	Dec. 16, 1910	Hillman	At shaft, split "A"	820	96,600	1.12	1,082	......
1211	do	do	At shaft, split "B"	756	75,600	.92	695	.10
2538	Apr. —, 1911	do	do	598	53,800	.55	296	.07
2540	do	Hillman - Abbott-Kidney.	At shaft, west side	562	66,300	.64	424	.07
1220	Dec. 16, 1910	Hillman	At west boundary, split "A."	241	20,485	.99	203	......
1210	do	do	At west boundary, split "B."	178	16,109	.88	142	......
2537	Apr. —, 1912	Kidney	150 feet from Hillman shaft.	432	18,100	1.26	242	.05

The total emanation of gas from the Dorrance mine was not ascertained, but on December 16, 1910, the Red Ash, Five-foot, Baltimore, and Hillman returns, which comprise the greater part of the working area, were giving off about 3,390 cubic feet of methane a minute. Early in April, 1912, the amount was 3,308 feet, and later in April, when mining had been suspended for nearly a month, the same returns carried 3,212 cubic feet of methane a minute.

AIR SAMPLES FROM RED ASH RETURNS.

Samples 1219, 1298, and 2531, which represent the entire return air from the Red Ash workings, were taken in No. 13 rock slope, through which this air was carried up to the Baltimore workings. One sample taken in December, 1910, contained 0.99 per cent methane, so that the return was passing 868 cubic feet a minute. A month later the proportion was 1.07 per cent, equivalent to a volume of 1,024 cubic feet a minute. The workings are under and north of the river, due north of Dorrance breaker, as shown in figure 28. They extend 2,800 feet west from the east line of the property and two of the slopes reach 1,000 and 1,200 feet north of the river. These slopes pass over a low anticline and some distance down its north side.

The depth beneath the surface varies from about 1,000 feet on the crest of the anticline to 1,050 and 1,150 feet in the synclines north and south. The average thickness of the bed is about 14 feet. The length of faces, pillars, gangways, and other coal surfaces in the workings was about 72,800 feet and as the average height is 14 feet there were 1,019,200 square feet of coal exposed. At the time of sampling there were 50 working faces, some of which were also mined on the night shift, so that there was a large area of fresh coal surface exposed. The gas is believed to be given off uniformly, the greatest amount coming from the working faces. If the total emanation of methane, 1,024 cubic feet a minute, be compared with the area exposed, it is equal to slightly more than 1 cubic foot a minute for each 1,000 square feet of coal surface, but doubtless the outflow was many times as much from working faces as from pillars. The production at time of sampling was 620 tons a day, including waste, so that the methane emanation was somewhat less than 2 cubic feet per minute for every ton mined.

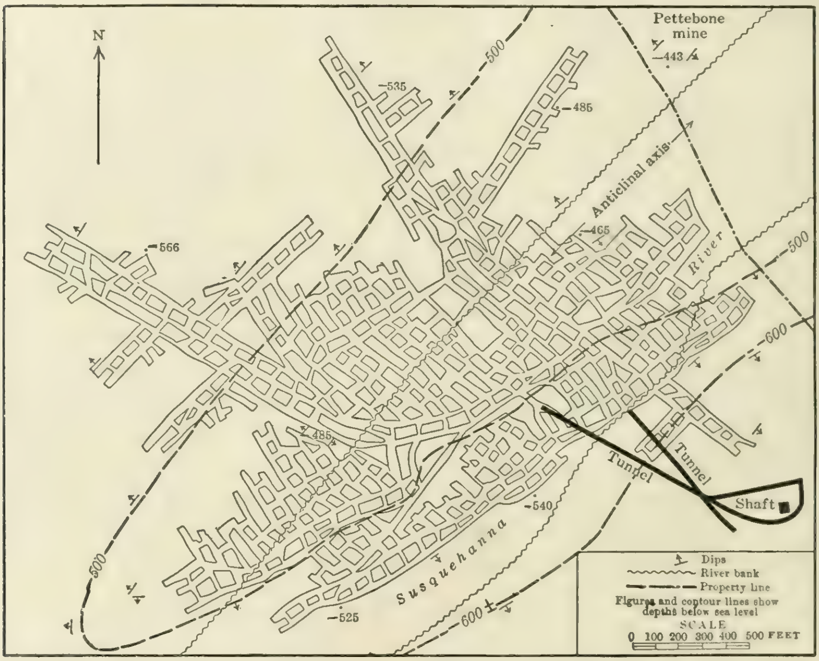


FIGURE 28.—Map of Red Ash workings in Dorrance mine, Wilkes-Barre, Pa.

COMPOSITION OF RED ASH COAL.

A sample of Red Ash coal was taken from a typical working face on January 2, 1911, 600 feet northwest of the main Dorrance shaft. The sample, which represents the entire face, was analyzed in the laboratory of the Bureau of Mines at Pittsburgh, with the following results.

Analysis of Red Ash coal from Dorrance mine, Wilkes-Barre, Pa.

[A. C. Fieldner, analyst.]

	Condition.			Referred to coal "moisture and ash free."
	Air dried.	As received.	Moisture free.	
Proximate analysis:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	[a]1.01	1.31	....	....
Volatile matter	5.70	5.68	5.76	6.21
Fixed carbon	86.13	85.87	87.01	93.79
Ash	7.16	7.14	7.23	....
Ultimate analysis:				
Hydrogen	2.33	2.35	2.23	2.40
Carbon	87.02	86.76	87.91	94.76
Nitrogen	.68	.68	.69	.74
Oxygen	2.39	2.65	1.51	1.64
Sulphur	.42	.42	.43	.46
Ash	7.16	7.14	7.23	....
Calorific value determined:				
Calories	7,677	7,654	7,756	8,360
British thermal units	13,819	13,777	13,961	15,048
Calorific value calculated from ultimate analysis:				
Calories	....	7,715	....	....
British thermal units	....	13,887	....	....

[a] Loss in air drying, 0.30 per cent.

AIR SAMPLES FROM BALTIMORE RETURNS.

The samples of air (Lab. Nos. 1300, 2534, 1299, and 2533) from the Baltimore workings were taken in the two outlets at the foot of the Baltimore upcast shaft. The air comprises not only the total return air from the Baltimore workings but also that of the Red Ash and Five-foot returns. The total volume of methane carried was 1,620 cubic feet a minute, but if the values for the Red Ash (1,024 cubic feet) and the Five-foot (about 250 cubic feet) be deducted, there remains only 346 cubic feet to the minute as the volume from the Baltimore workings. These workings extend under a large portion of the wide district lying between the Pettebone mine and North Market Street, Wilkes-Barre, and from the south side of the river north nearly to Rutter Street, as well as a small area southeast of the Dorrance shaft. In the north half of the area the Baltimore coal separates into two beds, the upper (7 feet thick) being known as the Cooper bed and the lower (6½ feet thick) as the Bennett, which are worked separately. The area of the workings, which are shown in figure 28, was approximately 1,000 acres, of which probably about one-third was pillars and two-thirds gangways and chambers. The workings were ventilated by about 200,000 cubic feet of air a minute, which, seemingly, carried only about 0.2 per cent methane. There were large areas of old workings, but considerable coal was being mined in places.

The workings extend over the prominent anticline just north of the river, the crest of which to the west develops into a 60 to 80 foot fault, and to the north descend 200 feet into a broad syncline traversed by a low anticline. The depth below the surface is mostly 600 to 800 feet and much of the area is covered by 50 to 100 feet of sand, gravel, and clay deposited by the Susquehanna River.

AIR SAMPLES FROM FIVE-FOOT RETURNS.

The return from the Five-foot workings could be sampled to advantage only at the head of No. 10 plane, or after it had ventilated about two-thirds of the worked area. As shown in Plate V this area, about 600,000 square feet, extends along the north side of the Susquehanna River just north of Dorrance breaker for about 2,000 feet east and west and 600 feet north and south. The beds dip gently 5° to 10° north into the main basin and are approximately 500 feet below the surface. The return sampled ventilated about 20 working faces which, with gangways and other spaces, had a length of about 15,000 feet. As the coal bed is 5 feet thick, 75,000 square feet of coal was exposed. The return air (sample 1221) carried 191 cubic feet of gas a minute, or about 2.5 cubic feet a minute for every 1,000 feet of coal surface. The amount of coal being mined was nearly 110 tons a day, including waste, so the methane was at the rate of about 1½ cubic feet a minute per ton.

AIR SAMPLES FROM HILLMAN RETURNS.

It was practicable to sample the Hillman returns at only two places, one in the main return at the foot of the upcast shaft, and the other in the main return near the west boundary of the property. The area of the Hillman workings in the Dorrance mine is shown in Plate V. The workings comprise a broad belt under the river and an extensive district to the northwest, covering in all about 220 acres. They extend across the prominent anticline previously mentioned and down into the syncline to the north, and the northernmost gangway passes over the next anticline north. The depth beneath the surface is mostly from 300 to 400 feet and except near the Dorrance shaft the the entire area is covered by about 100 feet of sand, gravel, and clay deposited by the river. The return air from the Hillman workings comes to the foot of the upcast shaft through two airways. One, carrying 1,082 cubic feet of methane (see sample 1212) a minute, is from the eastern and southern parts as far as the downcast at Thompson Street, Wilkes-Barre. To the east some miners were robbing pillars in an area filled by flushing. The thickness of the bed is about 6¾ feet.

One split ventilated a small area of workings in the Bowkley coal bed and then passed out the upcast, but this split carried little of the Hillman gas. The second airway, sampled at the foot of the main upcast (sample 1211) and carrying 695 cubic feet of methane a minute, received two splits: one drained new workings north of the river, where about 50 miners were employed, and a large area of old workings; the other was from workings that extended under the river and to the north as far as the west boundary.

The length of coal surface exposed in all chambers and gangways, as measured on the mine map, was approximately 160,333 feet, and as the average thickness of the bed is slightly over 6 feet, about 1,000,000 square feet of coal was exposed without deducting for certain areas that had been filled by flushing. As the total volume of gas in the two airways at the main upcast was 1,777 cubic feet a minute, 1.78 cubic feet of methane a minute was given off for every 1,000 square feet of coal exposed. Much more of this gas undoubtedly came from new workings than from old pillars and abandoned chambers.

The return air from the Hillman workings along the west boundary of the area was in two airways and these are represented by samples 1220 and 1210. One carried 203 and the other 142 cubic feet of methane a minute, a total of 345 cubic feet. This air finally joined other splits and was included in the air from which sample 1211 was taken. The extent of the area represented by this return air was large but was not ascertained.

RÉSUMÉ OF CONDITIONS IN DORRANCE MINE.

The amount of gas emanating from the different coal beds in the Dorrance mine varies widely and as the structural conditions are closely similar throughout, these variations are not related to the structure.

The Hillman workings, which present structural conditions similar to those of the Baltimore workings, but occupy a much smaller area (220 acres), were yielding 1,777 cubic feet of methane, equivalent to 1.78 cubic feet a minute to every 1,000 square feet of coal exposed. The Baltimore and Cooper-Bennett workings, having an area of nearly 1,000 acres and coal twice as thick, have a rate only about one-fiftieth as great, although certain places in these extensive workings are very gaseous. The Red Ash workings with only 84 acres mined but very thick coal gave slightly more than 1 cubic foot of methane a minute for every 1,000 square feet of coal exposed, or nearly 2 cubic feet a minute per ton mined. The Five-foot workings, 24 acres, were producing 2.5 cubic feet of methane a minute to every 1,000 feet of coal exposed, or slightly more than 1½ cubic feet a minute per ton mined. These figures, however, do not give as close a comparison as could be desired for the amount of gas given off per square foot in working faces is greater than in most old workings. The Five-foot and Red Ash workings contained a large proportion of fresh-coal exposures, whereas the extensive Hillman and Baltimore workings were in large part old, although in places they had many fresh working faces. The most notable features are the strong, general and local emanation of methane from the Hillman and Five-foot beds, the more moderate amount from the Red Ash bed and the very small general emanation from the extensive Baltimore workings.

HOYT MINE.

The Hoyt mine, which is one of the newer collieries of the Pennsylvania Coal Co., is in the center of the main basin 2 miles southwest of Pittston. Beds from the Pittston to the Red Ash, inclusive, are mined extensively. The workings are under the south side of the Susquehanna River for some distance and the northwest part of the mine extends under the river. North of the shaft there is a broad low anticline showing a number of crenulations to the northeastward. South of the shaft the measures slope into a shallow basin, in which the Red Ash bed is a few feet below sea level, and then rise very rapidly in a narrow steep-sided anticline, the crest of which is 238 feet higher than the bottom of the basin. This upturn is the southern margin of most of the workings, but the Red Ash bed has been followed up the rise by a gangway known as the south slope.

The mine is reported to be gaseous, especially in the workings under the river where the cover is thick and there is a sheet of clay in the valley filling. The sharp uplift south of the shaft was not as gaseous as was expected, but one heavy blower came from it in the workings in the Pittston bed. There have been several vigorous blowers in the mine. One, which continued to give off gas for many months, was from a crevice more than 16 feet deep. Another was in the roof at the end of the main gangway.

AIR SAMPLES FROM RED ASH RETURNS.

In investigating conditions in the Hoyt mine the Red Ash bed was selected because the amount of gas in its different returns varied considerably and the air currents were advantageously arranged for being sampled separately. The following table gives the results of analyses of five samples of return air, and the volume and velocity of the air at the points of sampling on November 18, 1910. The returns were also measured and sampled April 29, 1912, after mining had been suspended nearly a month. The results of the later work are given on page 145. In figure 29 are shown the extent of the workings in the Red Ash bed up to the end of 1910, the points at which air was sampled, the direction of the air currents, and the location of working faces.

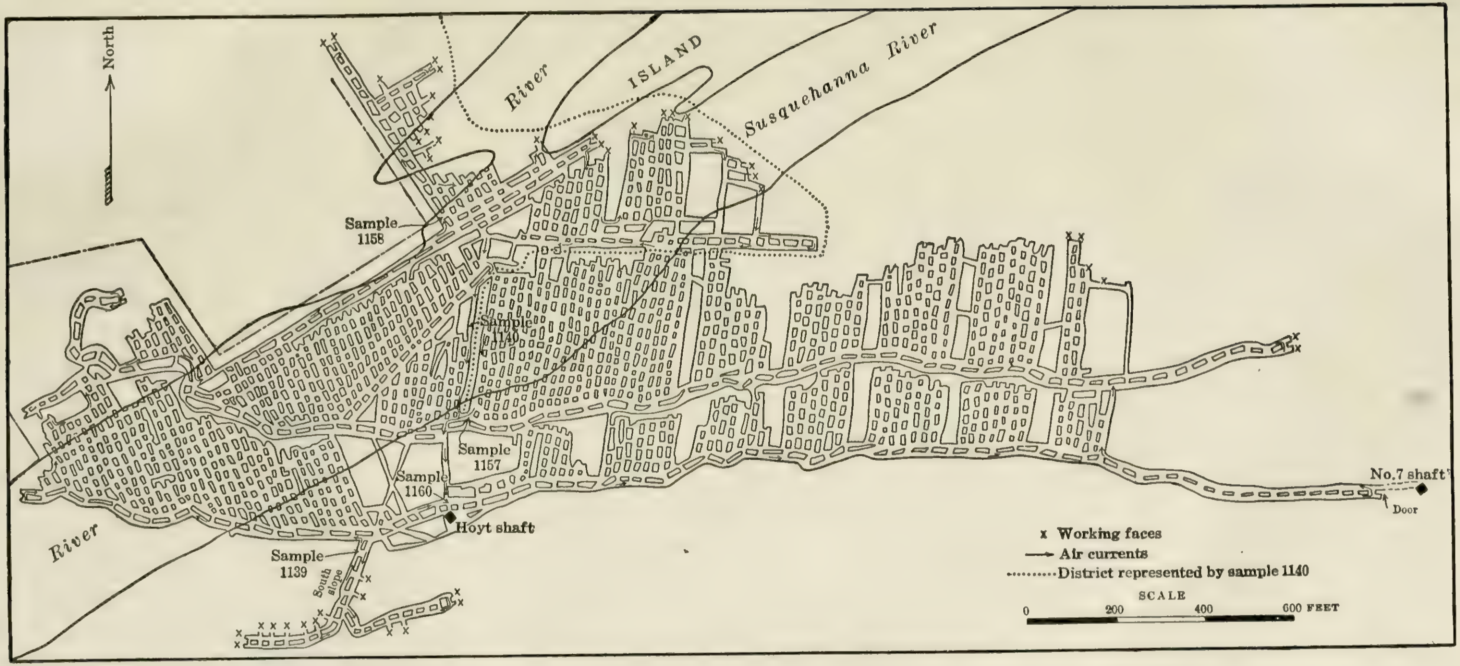


FIGURE 29.—Map of Red Ash workings in Hoyt mine, showing course of air currents sampled in November, 1910.

Analyses of return air in Red Ash workings, Hoyt colliery.

Laboratory No.	Return.	Place of sampling.	Air current.		Methane.		Carbon dioxide.
			Volume per minute.	Velocity per minute.	Proportion in mine air.	Volume per minute.	
			Cu. ft.	*Feet.*	*Per ct.*	*Cu. ft.*	*Per ct.*
1158	Red Ash	150 feet southwest of station 611, 106 feet above sea level.	22,491	306	1.27	286	0.05
1140	Red Ash, west split	Return from north of station 895.	16,626	978	1.53	254	.11
1157	Red Ash, east split	Station 679	33,804	485	1.36	460	.08
1160	Red Ash, main return	Near shaft	75,680	946	1.27	961	.08
1139	Red Ash, south slope	210 feet southwest of shaft	13,388	200	.94	126	.07

To ventilate the Red Ash workings in the Hoyt mine an air current of about 76,000 cubic feet a minute was used. It passed down the main shaft and was distributed through the mine in various splits. One larger split passed directly out through the east workings and then, circling to the north, drained all territory south and east of the dotted line in figure 29. The split was sampled at the place marked "sample 1157" (fig. 29), just inby the junction with other returns.

Another split ventilated the No. 1, or south slope workings, a small but gaseous district being actively mined. Beyond the point where sample 1139 was taken, the split turned west through a main airway, and finally, after dilution with about 50 per cent of fresh air, ventilated the west workings; then passing east for some distance it turned south at the place where sample 1158 was taken. Sample 1158 therefore represented the return air from No. 1 slope and that from the west workings, the ventilation of the latter being in part effected by fresh air direct from the downcast in the shaft.

Another split ventilated the small area of active workings north of the river, returned south, passed east through the workings under the river that are inclosed in the loop of the dotted line in figure 29, then west again, and finally it turned south along the west side of a narrow pillar which separates the ventilation of the east workings, and passed the point where sample 1140 was collected.

One hundred yards south of the place where sample 1140 was taken this air joins the air from the east workings in a main return which 200 feet farther south reaches the upcast at the shaft, where sample 1160 was taken.

RÉSUMÉ OF CONDITIONS IN RED ASH WORKINGS.

The analyses of the samples taken show no great variation in the amount of methane in different parts of the Red Ash workings, if the relative extent of the workings and of fresh surfaces be considered. The air in sample 1157 (see fig. 29) represents a large territory, mostly of old workings, and carries 460 cubic feet of methane a minute. The very small area of active mining on the uplift on the south slope yielded methane at the rate of 126 cubic feet a minute. The west workings (sample 1158) yielded 160 cubic feet of methane a minute from a district that is large but was not being mined at the time of sampling.

The air from the north workings, which include an area where are many undulations of the strata, is represented by sample 1140. This return ventilates a part of the mine which was of small extent, but was being actively mined and was giving off considerable gas. It carried 254 cubic feet of methane a minute, or little less than the volume from the large area of old workings on the west side. The aggregate volume of methane in the three returns was 1,000 cubic feet a minute when measured separately and 961 cubic feet a minute in the total return at the shaft upcast.

MINE NO. 14, NEAR PITTSTON.

The large No. 14 mine of the Pennsylvania Coal Co. is near the south bank of the Susquehanna River about 3 miles southwest of Pittston. The coal measures here are in a deep basin and along the river flat they are covered by beds of sand, gravel, and clay that in places aggregate more than 100 feet thick. There are several important beds of coal, but the principal workings are in the Pittston, Checker, Diamond, and Hillman beds. The mine has always been classed as gaseous and has had numerous small gas explosions.

AIR SAMPLES.

As the workings differ considerably as to depth, structure, and amount of gas given off in different places, samples of air were collected in the principal returns to detect variations that might be connected with special conditions. The places at which the samples were taken and the ventilation that some of them represent are shown in Plate VI. The samples were analyzed at the Pittsburgh laboratory of the Bureau of Mines with the following results:

Analyses of return air in No. 14 mine.

[G. A. Burrell, analyst.]

Lab. No.	Return.	Place of sampling.	Air current.		Methane.		Proportion of carbon dioxide in mine air.
			Volume per minute.	Velocity per minute.	Proportion in mine air.	Volume per minute.	
			Cu. ft.	*Feet.*	*Per ct.*	*Cu. ft.*	*Per ct.*
1153	Pittston bed, first slope....	Head of motor plane......	26,520	1,020	0.89	236	0.14
1152	Pittston bed, main return.	North pitch workings.....	16,560	238	.72	119	.10
1151	.....do.....................	Rise to Marcy bed, near shaft.	22,360	860	.47	105	.11
1150	.....do.....................	Near shaft................	104,728	848	[a] .41	429	.13
1154	Checker bed, main return..	Near upcast...............	147,700	1,692	.26	384	.09

[a] Another sample gave 0.40 per cent.

AIR SAMPLES FROM PITTSTON RETURNS.

The first sample (Lab. No. 1153), taken in the return at the head of the motor plane in the first slope, where there were 25 working faces, represented an area of workings about 200 feet wide and 1,400 feet long, most of which was under the river. The return carried 236 cubic feet of methane a minute.

Sample 1152 was taken in the main return from the north pitch workings, which are nearly all under the river and Monocanock Island. The workings,. which had 12 working faces, were 1,400 feet long by 200 to 450 feet wide. The return air carried 0.72 per cent methane, or 119 cubic feet a minute.

Sample 1151 was taken from an extension of the return from which sample 1152 was taken, at a rise up which the current was carried to ventilate the workings in the Marcy bed. The return gained somewhat in volume by leakage inward through doors near the shaft, so that at this place it had a volume of 22,360 cubic feet per minute and carried only 0.47 per cent of methane, or 105 cubic feet a minute.

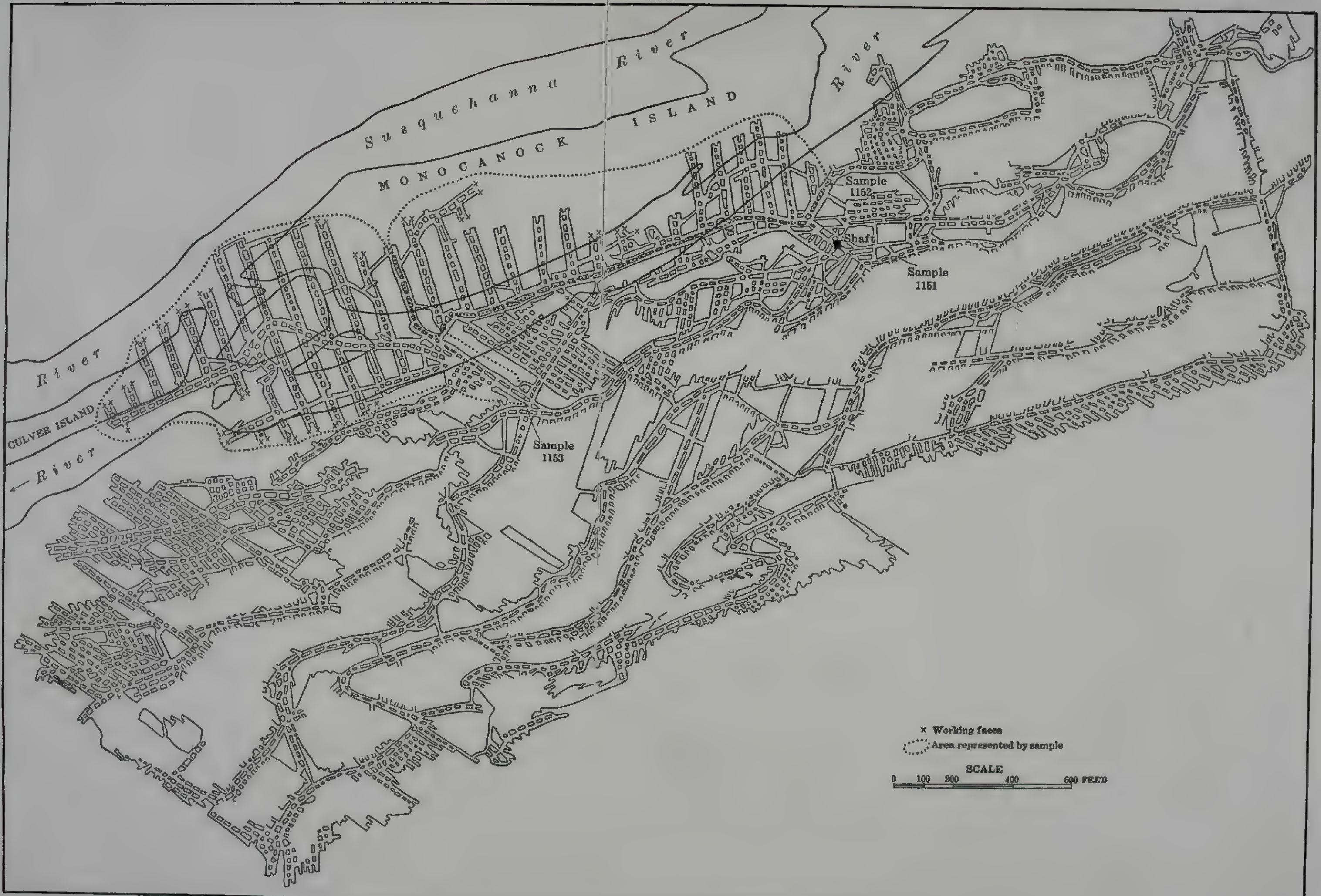
Sample 1150, taken in the main Pittston return near the shaft, represented all the return air from that bed except the part represented by sample 1151, which passed into the Marcy workings. The return air, which had a volume of 104,728 cubic feet a minute, carried 0.41 per cent of methane, so that a total of 429 cubic feet of methane a minute was passing up this upcast.

AIR SAMPLE FROM CHECKER RETURN.

A sample (Lab. No. 1154) was taken of the main return from workings in the Checker bed. This coal varies from 3½ to 7 feet in thickness and was being worked about as extensively as the Pittston bed in the same area, with 85 working faces. The return near the shaft was passing 147,700 cubic feet of air a minute, carrying 0.26 per cent methane, or 384 cubic feet a minute. The close similarity between the volume of methane in this return and that in the main upcast from the Pittston bed is interesting. The Pittston bed is very much thicker and has more extensive old workings, a fact that indicates that the Checker bed is giving off much more methane for each square foot of coal exposed.

COMPOSITION OF PITTSTON COAL.

A sample of coal from the Pittston bed in the No. 14 mine was collected November 21, 1910, from a working face near station 4695 on the Brannagan slope. It represented the entire face except a thin parting of bony coal which was rejected. The sample was analyzed in the laboratory of the Bureau of Mines at Pittsburgh with the following results.



MAP OF WORKINGS IN PITTSTON BED, NO. 14 MINE, PA.

Results of analysis of coal from Pittston bed in mine No. 14, 3 miles southwest of Pittston, Pa.

[A. C. Fieldner, analyst.]

	Condition.			Referred to coal. "Moisture and ash free."
	Air dried.	As received.	Moisture-free.	
Proximate analysis:				
Moisture	[a]0.60	2.19		
Volatile matter	5.76	5.67	5.80	6.17
Fixed carbon	87.64	86.24	88.17	93.83
Ash	6.00	5.90	6.03	
	100.00	100.00	100.00	100.00
Ultimate analysis:				
Hydrogen	2.56	2.70	2.52	2.68
Carbon	87.77	86.37	88.30	93.97
Nitrogen	.92	.91	.93	.99
Oxygen	2.17	3.55	1.64	1.74
Sulphur	.58	.57	.58	.62
Ash	6.00	5.90	6.03	
	100.00	100.00	100.00	100.00
Calorific value determined:				
Calories	7,807	7,682	7,854	8,358
British thermal units	14,053	13,828	14,137	15,044
Calorific value calculated from ultimate analysis:				
Calories		7,771		
British thermal units		13,988		

[a] Loss in air drying, 1.60 per cent.

SLOAN MINE.

The Sloan mine is situated in the outskirts of Scranton, its shaft being 2 miles west of the city hall. There are extensive workings in the upper beds, but the No. 2 Dunmore or lowest bed had only recently been opened. A moderate amount of gas had been encountered in this bed and the proportion of it in the returns varied markedly in different parts of the workings. After many mines in the Lackawanna Valley had been inspected in order to ascertain the conditions under which gas occurred it was decided that the Dunmore workings at Sloan presented particularly favorable conditions for special study of the escape of gas. The area of the workings was relatively small, the air currents were so apportioned that their composition was representative of the air in the separate parts of the mine which they ventilated, and the structural conditions presented certain marked variations.

AIR SAMPLES FROM DUNMORE RETURNS.

A time was selected when atmospheric and other conditions were normal and the miners were evenly distributed through the working faces in the different parts of the mine. Two foremen perfectly familiar with the ventilation system conducted the author through the returns to points where he could collect samples representing the gaseous emanations from definable districts in the workings. Five such samples (Lab. Nos. 1234, 1235, 1237, 1238, and 1239) were obtained and a sixth sample (Lab. No. 1236) was taken to represent the total return near the foot of the main upcast at the foot of the shaft.

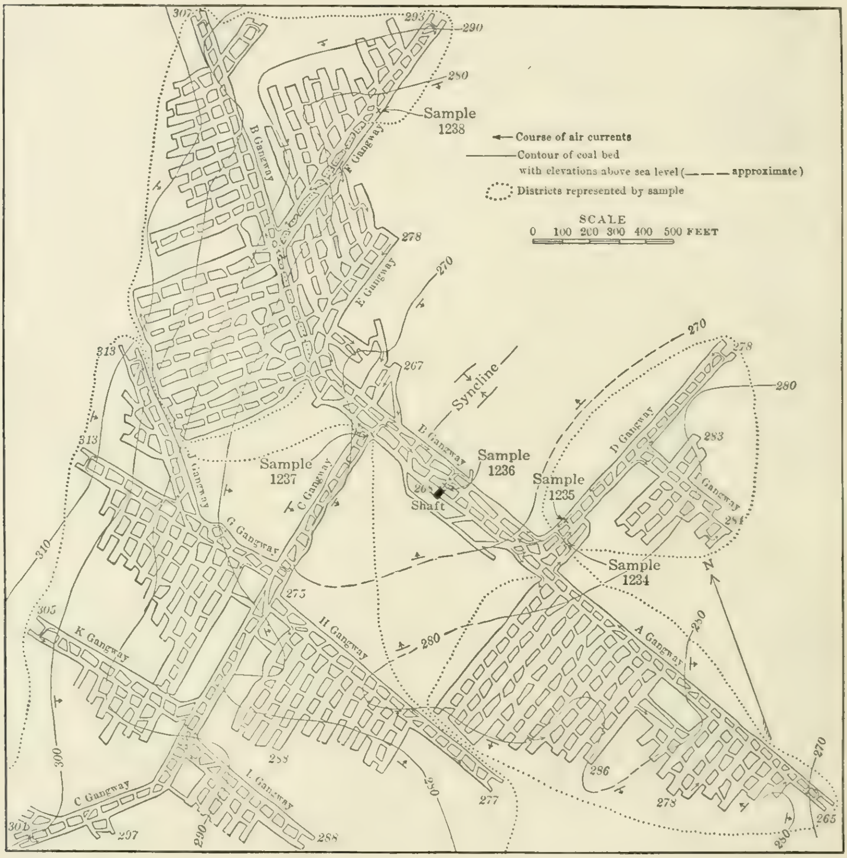


FIGURE 30.—Map of workings in Dunmore bed, Sloan mine.

Cross sections of gangways were measured and duplicate anemometer readings made at each place. The points at which samples were taken are shown in figure 30.

The samples were analyzed at the Pittsburgh laboratory of the Bureau of Mines with the following results.

Analyses of return air in Dunmore workings, Sloan mine.

[G. A. Burrell, analyst.]

Lab. No.	District in workings.	Air current.		Methane.		Carbon dioxide.
		Volume per minute.	Velocity per minute.	Proportion in mine air.	Volume per minute.	
		Cubic feet.	*Feet.*	*Per cent.*	*Cubic feet.*	*Per cent.*
1234	Gangway A	15,794	175	1.02	161	0.06
1235	Gangways D and I	15,470	160	.65	101	.03
1237	Gangways C, G, H, J, K, and L	45,800	382	1.08	495	.09
1238	Gangways B and F	15,270	402	.08	12	.09
1239	.....do	1,065	142	.03	4	.07
1236	Total return	94,080	980	.70	659	....

In the development of the Dunmore workings the greatest outflow of gas was found in gangways H and L (included in sample 1237) and in gangway A (sample 1234). In gangways B and F (sample 1238) no gas had been reported and it was seldom appreciable by lamp test in the headings. In gangways A, H, and L notable amounts of gas were found in all the headings, but the amount varied at different headings and at the same heading. Many "blowers" have been encountered and sometimes these have been ignited, but without causing any special damage. All the holes drilled for shots gave off more or less gas.

STRUCTURE OF DUNMORE BED.

The structure of the Dunmore bed in the workings at the Sloan mine is shown in figure 30 by contour lines with 10-foot intervals. It may be seen from this map that the strata are only slightly disturbed from their original horizontal position and have about the same average elevation above sea level. At the shaft and to the east there is a shallow syncline or basin the axis of which rises gently to the southeast in the area represented by sample 1237. That area in fact is in beds dipping gently to the eastward with a slight rise over a low anticline on gangways H and L and a steeper upgrade on gangway I. Sample 1234 represented the air from an area occupied by the eastward extension of the anticline first mentioned, but at the further end the workings cross a very shallow basin and rise over a low local uplift. Sample 1235 was from an area where the beds are nearly horizontal or dip gently north on the south side of the central syncline. Sample 1238 was taken at a point on the north side of the syncline, opposite sample 1235, where the dips are steeper. The coal on this side rises from an altitude of 280 feet along gangway F to 312 feet in the easternmost working faces off gangway B. The dip in this rise, however, is only 3°.

No notable faults or breaks were observed.

CHARACTER OF DUNMORE COAL.

The No. 2 Dunmore bed is 4 to 4½ feet thick in the gaseous workings south of gangways A, H, and L. To the north in the nongaseous region the coal is in two beds, 2 to 2½ feet of rock separating the upper bed, which is 2 feet thick, from the lower bed, which is 1 foot thick. The gaseous coal is dry and hard and contains considerable dirt, whereas the nongaseous coal has a much larger moisture content and is softer.

A representative sample of coal from the most gaseous part of the Dunmore No. 2 bed in the Sloan mine was taken from the heading in gangway H on December 5, 1910, and analyzed in January, 1911, in the laboratory of the Bureau of Mines at Pittsburgh with the following results:

Results of analysis of coal from Dunmore No. 2 bed, Sloan mine, near Scranton, Pa.

[A. C. Fieldner, analyst.]

	Condition.			Referred to coal "Moisture and ash free."
	Air dried.	As received.	Moisture free.	
Proximate analysis:				
Moisture	[a] 0.95	3.43	....	....
Volatile matter	6.96	6.79	7.03	7.98
Fixed carbon	80.26	78.25	81.03	92.02
Ash	11.83	11.53	11.94	....
	100.00	100.00	100.00	100.00
Ultimate analysis:				
Hydrogen	2.30	2.52	2.22	2.52
Carbon	80.87	78.85	81.65	92.72
Nitrogen	.79	.77	.80	.91
Oxygen	3.74	5.87	2.91	3.30
Sulphur	.47	.46	.48	.55
Ash	11.83	11.53	11.94	....
	100.00	100.00	100.00	100.00
Calorific value determined:				
Calories	7,283	7,101	7,353	8,350
British thermal units	13,109	12,782	13,235	15,030
Calorific value calculated from ultimate analysis:				
Calories	....	6,998	....	....
British thermal units	....	12,596	....	....

[a] Loss in air drying, 2.48 per cent.

AMOUNT OF METHANE IN RELATION TO AREA OF COAL EXPOSED.

The chambers and gangways shown in figure 30 were measured with a chartometer to ascertain the total length of all excavations in each district represented by samples 1234, 1235, 1237, 1238, and 1236. Multiplying the length of excavation by the average height of the coal exposed, 4½ feet in districts south and 3 feet in districts north of the shaft, gives the approximate number of square feet of coal exposed.

Volume of methane relative to area of coal exposed, Sloan mine.

Laboratory number of sample.	Return.	Area of coal exposed.	Volume of methane per minute per 1,000 square feet of coal exposed.	Area of coal exposed to each cubic foot of methane.
		Sq. feet.	*Cu. feet.*	*Sq. feet.*
1238	Gangways B and F	81,900	0.15	6,825
1237	Gangways C, G, H, J, K, and L	151,300	3.26	305
1235	Gangways D and I	30,175	3.37	299
1234	Gangway A	87,975	1.81	547
	Region between samples 1238 and 1236	35,100	....	....
1236	Total return	386,450	1.70	586

The most noteworthy feature shown in this table is that the relatively large area of coal in the district represented by sample 1238 was giving off remarkably little methane. Sample 1237 represented air containing gas from a large amount of coal in pillars, chambers, and gangways, so that the amount of methane per square foot was less than for the small area in the district represented by sample 1235, which, however, gave off only 101 cubic feet of methane a minute, whereas the district represented by sample 1237 was giving off 495 cubic feet. This indicates that a large part of the workings drained by the return in which sample 1237 was taken was not especially gaseous, the large emanations coming from headings and new chambers. A sample (Lab. No. 1239) of the return air in gangway E representing the short interval of gangways and chambers between gangway F (sample 1238) and the main upcast (sample 1236) near the shaft had practically the same methane content as sample 1238.

CARBON DIOXIDE IN MINE AIR.

In four samples the carbon dioxide content was determined. The average proportion in the mine air was about 0.05 to 0.08 per cent in excess of that in ordinary atmospheric air. With the volume of the upcast air 94,080 cubic feet a minute, this 0.08 per cent amounts to only 75¼ cubic feet of carbon dioxide a minute, or not much more than one-tenth as much as the volume of methane. Doubtless this is not much more than should be expected from blasts, lights, the breath of men and mules, and various minor sources.

CHANCE OF LEAKAGE OF GAS TO HIGHER WORKINGS.

Above the Dunmore workings in the Sloan mine is an extensive mined area in the next coal bed known as the Clark. Between the two beds are sandstone and clay beds 163 feet thick which seemingly were so nearly impervious that little gas could escape through them. Moreover, the strata are so regular that any possible leakage would probably be uniform throughout the area. Some years ago a considerable flow of gas was found coming up through a crack in the floor of the Clark workings, presumably from the Dunmore coal below. The crack was cemented and a pipe set into it to conduct the gas to the main upcast.

EFFECT OF CESSATION OF MINING ON MINE AIR.

RESULTS OF SAMPLING AIR OF IDLE MINES.

During April, 1912, the mines in the anthracite field were closed because of a strike. Advantage was taken of this circumstance to collect air from several of the mines at the same localities as in previous visits in order to make a comparison between the outflow of methane during mining and that at a time when there had been no mining for a month previous. In most mines the volume of ventilating air was greatly reduced during the period of no mining, so that if much of the methane normally in the return air is given off by the great area of ribs and pillars the percentage of methane would be expected to increase in the returns. This proved to be the case in some instances, but in most of the returns the volume of methane had diminished considerably and with many unexpected variations. In a few workings there had been some slight changes in arrangement of the air currents so that exact comparison could not be made. The samples collected were analyzed in the laboratory of the Bureau of Mines at Pittsburgh. A comparison of the results with those obtained from the samples collected in the same place in December, 1910, and January, 1911, is presented in the table following.

Methane in return air during mining (November, 1910, to January, 1911) and after mines had been shut down nearly a month (April, 1912).

[G. A. Burrell, analyst.]

Mine.	Return.	November, 1910, to January, 1911.		April, 1912.	
		Proportion of methane in mine air.	Volume per minute.	Proportion of methane in mine air.	Volume per minute.
		Per cent.	*Cubic feet.*	*Per cent.*	*Cubic feet.*
Lance	Bennett and overlying beds, total upcast, No. 1 air shaft.	0.96	[a] 1,920	....	....
Do.	Red Ash bed, total upcast, No. 2 air shaft.	1.07	1,067	....	....
Do.	Ross, total upcast, No. 5 slope	1.46	714	[b] 2.29	1,375
Do.	Total upcast	....	[c] 2,691	1.56	[a] 3,120
Do.	Cooper, west, No. 11 tunnel	2.68	508	2.98	678
Do.	Cooper, east, No. 23 tunnel	1.04	431	1.55	471
Do.	Five-foot, east, at No. 7 slope	1.46	383	[d] 3.06	[d] 416
Do.	Five-foot, west, at No. 7 slope	.23	65	[e] 2.20	[e] 523
Do.	Hillman, east, No. 14 tunnel	1.50	555	2.64	706
Do.	Hillman, west, No. 14 tunnel	.55	167	[f] 1.56	[g] 147
South Wilkes-Barre (No. 5).	Total upcast of all beds	.72	2,269	.71	2,231
Do.	West Hillman returns	1.43 .67	432 124	2.96	611
Do.	Abbott workings north of shaft 5, plus Stanton No. 5 return and Hillman No. 4 tunnel.	.43	501	1.93	800
Do.	Total Abbott workings south of shaft	1.14	230	.55	51
Dorrance	Return from Red Ash	[h] .99	865	1.03	927
Do.	do	1.07	1,024		
Do.	do	[i] 1.34	1,080		
Do.	Baltimore return, from Baltimore Red Ash and Five-foot beds, north side	.49 [i] .73	968 1,161	.47	973
Do.	Baltimore return, from Baltimore, Red Ash and Five-foot beds, south side	.64 [i] 1.02	652 1.427	.77	1,375
Do.	Five-foot return (⅔)	[i] .84 [h] 1.38	157 191	1.16	299
Do.	Hillman returns, 2 splits	[h]92 to 112 [i].55 to.64	1,777 720	.36 to .71	864
Hoyt	Red Ash return, 150 feet southwest of station 611.	[j] 1.27	286	1.53	229
Do.	Red Ash, return from No. 1 slope	[j] .94	126	1.29	80
Do.	Total return, Red Ash	[j] 1.27	961	1.53	475
Sloan	Dunmore workings, gangway A	[h] 1.02	161	.51	147
Do.	Dunmore, gangways D and I	[h] .65	101	.31	77
Do.	Dunmore, gangways C, G, H, J, K, and L.	[h] 1.08	495	.76	296
Do.	Dunmore, gangways B and F	[h] .08	12	.0	0
Do.	Dunmore, total return	[h] .70	659	.49	464

---

[a] Air volume, 200,000 cubic feet a minute.

[b] No. 3 slope, total Red Ash and Ross returns.

[c] Sum of three preceding figures.

[d] Not worked for several months. Ventilated by split from Ross-Red Ash air, the methane of which is not subtracted.

[e] Now on split of air from Ross-Red Ash workings, the methane introduced by that air not subtracted.

[f] Ventilated by air from split of Ross-Red Ash air, carrying 1.27 per cent methane, or 217½ cubic feet a minute.

[g] Total result, less 217½ cubic feet from Ross-Red Ash split.

[h] December, 1910.

[i] Sampled by H. I. Smith, early in April, 1912.

[j] November 19, 1910.

DISCUSSION OF RESULTS.

These figures indicate that with the cessation of mining the emanation of methane diminished in some places whereas in others it did not. In some of the workings the volume of methane in samples taken after four weeks of cessation was greater than when the sampling was done in December, 1910, or in January, 1911. Of course the comparisons would have more value if the first set of samples had been taken immediately before mining ceased, for doubtless there had been some changes in the volume of gas given off during mining after the earlier sampling.

LANCE MINE.

There was an increase of nearly 20 per cent in the methane in the total upcast air in the Lance mine, if it be assumed that fan No. 2 was moving 200,000 cubic feet of air a minute on both occasions. It happened that at this fan the volume could not be measured satisfactorily. Only this one fan was working during the shut down and therefore the volume of air coming out of the mine was considerably diminished. At this time also the Red Ash and Ross air came to this fan, after being used en route for ventilating workings that formerly had been on fresh-air splits. Increased methane emanation is shown in the Cooper and east Hillman returns, the Hillman workings being ventilated by a split of Ross-Red Ash air at the time the second sample was taken. Both the east and west workings in the Five-foot bed were also ventilated by a split of Ross-Red Ash air, but the proportion of methane in this split was not tested at the intake on April 27, so that the increment of methane that this air received in passing through the Five-foot workings is not known.

SOUTH WILKES-BARRE MINE.

The cessation of mining appears to have had slight effect on methane emanation in the South Wilkes-Barre mine except perhaps to cause a marked diminution in the volume from the south workings in the Abbott bed. The north workings in the Abbott and Hillman beds show material increase. The fan was running at the same speed at each time of sampling, 45 revolutions per minute. The volume of air delivered, which was measured in December, 1910, was approximately 315,083 cubic feet a minute.

DORRANCE MINE.

The Dorrance mine shows frequent variations in methane emanation and the volumes found on April 27 do not show much diminution due to the cessation of mining. The volume furthermore in the total Hillman return was less than when tested $1\frac{1}{4}$ years before, but greater than when sampled by H. I. Smith the month before.

In the return from the south half of the Baltimore workings there was slight increase in methane content; in the Five-foot returns, a decided increase; and in the Red Ash returns, a material increase.

HOYT MINE.

The volume of methane in all the Red Ash returns in the Hoyt mine decreased after mining had ceased, the total volume diminishing 50 per cent, and that in the return from No. 1 slope, 30 per cent.

SLOAN MINE.

In the Dunmore workings in the Sloan mine there was a marked decrease in the amount of methane during the four weeks of no mining, the total volume dropping from 619 to 404 cubic feet a minute, the amount in all of the gangways lessened correspondingly, the emanation diminishing to 60 per cent in the very gaseous C, G, H, J, K, and L gangways, and to zero in the B and F gangways, which had been only slightly gaseous.

RÉSUMÉ.

The causes of variations in the methane emanation during the period of no mining are not at all clear. On the whole there was a marked decrease, which was to be expected, because less fresh coal was being mined and the gangways and workings were not being advanced into undrained territory, but on the other hand, the results show that some districts continue to give off the same amount of gas as when mining was active, and in places there was a marked increase. It was not possible to connect these places with differences in structural features (anticlines, synclines, or faults) nor to show that the greater escape of gas was due to crushing or creeping, or to differences in composition or texture of roof, floor, or adjoining beds, all of which may in certain places be factors of some importance.

MISCELLANEOUS OBSERVATIONS IN MINES IN THE ANTHRACITE FIELD.

MINES IN AND ABOUT SCRANTON.

Many of the mines about Scranton were inspected in the course of the investigation. The mines are extensive and include vast areas of old workings which are not especially gaseous. Gas in this district appears mostly in the working faces and occurs very irregularly. In general, the total volume of methane is not nearly so large as in the Pittston-Wilkes-Barre district. The smaller volume is due partly to the proximity of the coal to the surface and partly to the extent of the old workings, which have drained off part of the gas. Usually the largest volume and most noticeable manifestations of gas are in the Dunmore beds near the base of the measures.

BELLEVUE AND PANCOAST MINES.

In the lower part of the Bellevue mine in Scranton the working faces of the Dunmore bed are very gaseous in places.

In the Pancoast mine at Throop the fresh workings in the Dunmore No. 1 bed are especially gaseous, and blowers occur at intervals. The fresh coal gives off so much methane that the gas can be ignited by placing a light between the lumps in a car, and blasting often lights gas in crevices in the solid, so that water service for extinguishing such fires has to be maintained at the working breasts. The author noted several vigorous blowers in workings in this mine under the Lackawanna River and on the slopes south. The measures dip gently to the northwest. At one point there is a sharp synclinal crumple in the lower beds, on one side of which there is much more gas than on the other side, but no reason for the difference was apparent. Bore holes sunk to the Dunmore bed from the Clark workings emitted a large volume of gas and one of them also had a flow of water.

MARVINE MINE.

At the Marvine mine, just north of Scranton, considerable gas was being given off in the Dunmore workings, the amount increasing in slips and breaks and in the workings under the river. Some years ago a strong blower was opened in the workings of the next bed above (Clark). The gas, which was under great pressure, was finally controlled and utilized by cementing a pipe into the rock and leading the gas to the surface. The flow continued for a long time.

DICKSON MINE.

In the Dickson mine in Scranton the conditions are similar to those in the Marvine mine, as the Dunmore bed gives off much gas in the fresh workings. Several roof feeders were opened, but they have been finally exhausted. The workings extend to the bottom of the syncline under the river, but the amount of gas appeared to be less in the deeper chambers than in districts where the beds are locally arched or broken.

GREEN RIDGE AND DIAMOND MINES.

In the Green Ridge mine, in the northern part of the city of Scranton, the coal is much nearer the surface and gives off less methane, except in a few places in the Dunmore No. 2 bed.

In the Diamond mine, near the center of the city, the Dunmore beds are about 450 feet below the surface in the bottom of the basin. Tests of gas in returns from No. 1 and No. 2 Dunmore beds and the New County bed on February 8 to February 10, 1910, made by the Delaware, Lackawanna & Western Coal Co. showed 0.2 and 0.3 per cent of methane except in the Riverside return, No. 1 Dunmore, where 0.6 per cent was found. The total volume of the air currents measured was 95,600 feet per minute and the total volume of methane in them was 246 cubic feet a minute, which is very little in comparison with some returns in mines near Wilkes-Barre.

STORRS, CAYUGA, AND BRISBIN MINES.

The extensive workings of the Storrs mine are largely in the rise toward the northern outcrop of the beds on the slopes north of Providence. The conditions governing the occurrence of gas in this mine are fairly typical of wide areas along the north margin of the basin of the Scranton region. The results of numerous tests of the gas in the returns from the Dunmore, Clark, Pittston, Diamond, and other beds were given to the author by the Delaware, Lackawanna & Western Coal Co. The volume of the air currents tested ranged from 7,200 to 45,000 cubic feet a minute. In most of the returns there was no appreciable methane or but a trace. At a few places the methane content was 0.1 to 0.2 per cent, and in one restricted area the content in a current of 19,125 feet was 1.1 per cent.

Similar conditions were found in the Cayuga mine, where it is reported that samples taken in February, 1910, from returns from the Rock bed, the Four-foot bed near the shaft, and at the head of the Dunmore slope show no trace of methane. Tests made by the company at the same time in the Brisbin mine showed only traces and up to 0.1 per cent of methane in returns from the Dunmore, Clark, Diamond, and Rock beds. One return of 40,000 cubic feet from extensive old workings in the Clark bed carried only 0.1 per cent, or 40 cubic feet of methane a minute.

MANVILLE AND GRASSY ISLAND MINES.

In the Manville mine in Scranton the workings are in the south slope of the basin. The results of some tests of returns made in February, 1910, have been reported to the author by the Delaware, Lackawanna & Western Coal Co. The Dunmore returns carried methane from a trace to 0.2 per cent except in the east split return from No. 2 Dunmore where there was no trace of methane. It would appear from the analyses that the total emanation of methane from the Dunmore workings of this mine was somewhat less than 200 cubic feet a minute. The Dunmore return air, near fan No. 1, carried 0.1 per cent of methane in a current of 93,600 cubic feet a minute, or nearly 194 cubic feet of methane a minute.

A remarkable sporadic area of increased methane emanation was observed at Grassy Island No. 2 shaft, near Olyphant. At this place, the Dunmore bed No. 4, which is about 6 feet thick and has a heavy layer of sandstone over it, had been notably gaseous and the roof and floor had numerous small feeders in them. Bed No. 3 was also gaseous but was being worked only to a small extent. The measures are very regular and there seems to be no explanation for the amount of methane in this mine being much greater than in those adjoining, other than some variation in the character of the coal itself.

MINES BETWEEN PITTSTON AND HUDSON.

Beside the detailed investigations in the Lance, Dorrance, South Wilkes-Barre, Hoyt, and No. 14 mines, many data were obtained as to some of the conditions in various mines in the region between Pittston and Wilkes-Barre. Several mines were also visited by H. I. Smith in the spring of 1912 for the purpose of collecting samples of return air, which were analyzed at the Pittsburgh laboratory of the Bureau of Mines. Several analyses of air from the Pettebone mine were kindly supplied by the Delaware, Lackawanna & Western Coal Co.

MINE NO. 6.

Parts of mine No. 6 of the Pennsylvania Coal Co., near Inkerman, were decidedly gaseous. There are many small abrupt flexures in the measures in this mine, but the occurrence of gas seems to bear no relation to them, as most of the gas is given off in certain zones of solid coal that show no signs of disturbance. The Clark bed has several strongly gaseous areas. In one place, where there was some local faulting of the beds and the coal was considerably crushed, there were several small blowers in the floor of the gangway. Although the blowers were conspicuous because of the noisy bubbling, the amount of gas produced was probably much less than in some of the fresh workings. Another blower in the Marcy workings, at a place where the beds suddenly pitch up a few feet, was seemingly coming from a crack in the bottom or side of the small syncline so formed.

PINE RIDGE MINE.

The Pine Ridge mine of the Delaware & Hudson Coal Co. northeast of Wilkes-Barre has been in operation many years and is still producing a large tonnage. All of the usual beds are being worked, and the lowest beds are 500 to 700 feet below the surface in a large part of the area. The principal structural feature is a syncline, but there are many subsidiary flexures, some of them sharp enough to be called faults. Some parts of the mine were gaseous and certain places gave off a very large amount of methane. An instance is on record [a] of a flow of gas from the roof in a small syncline which required an air current of 15,000 cubic feet a minute to keep the proportion of methane below the explosion limit. At one time the mixture ignited for 150 feet along the roof, although 25,000 cubic feet of air per minute was passing.

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[a] Anon., Fire damp in the anthracite mines: Eng. and Min. Jour., vol. 17, 1874, pp. 33–34.

Several large feeders occurred in bottoms of synclines, especially in two with a low arch between them. It was noted in this vicinity that an underlying bed may be less gaseous, under the same structural conditions, than the bed above. One gaseous belt was in an anticline in which the coal rose to the cap of alluvium and considerable gas was found in places above water level even with only 20 to 30 feet of cover. At the time of the author's visit there was much gas in all the lower beds and workings, especially in the Ross bed where there was an old blower. This blower came from near the crest of an anticline, and a bore hole on the crest tapped a large volume of gas from the Red Ash bed some distance below. In years past much gas was found at intervals even in the higher beds along some of the "faults" mainly in the form of blowers or rapid gas emanations, which caused several explosions. Some bore holes in this area tapped large volumes of gas and in two of them gas has been flowing out of the pipe at the surface for many years.

Several samples of return air in the Pine Ridge mine were taken by H. I. Smith on March 16, 1912, and were analyzed with the following results:

Results of analyses of air samples from returns in Pine Ridge mine.

[G. A. Burrell, analyst.]

Lab. No.	Return.	Place of sampling.	Air current.		Proportion of gases in mine air.			Volume of methane per minute.
			Volume per minute.	Velocity per minute.	Methane.	Carbon dioxide.	Oxygen.	
			Cu. ft.	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cu. ft.*
2427	Red Ash	No. 17 plane	32,000	368	0.17	0.07	....	54
2398	Cooper, Bennett, and Checker.	Total return in air tunnel Cooper to Rock.	110,800	1,273	.16	.13	....	177
2525	Hillman	No. 15 slope	16,300	354	.05	.08	20.33	80
2527	do	Second east off No. 13 slope, 2,500 feet from air shaft.	7,500	257	.04	.00	20.68	3
2528	do	do.[a]	....	....	.02	.02	20.74	2
2521	Kidney	Tunnel Kidney to Hillman.	18,800	348	.00	.07	20.67	0

[a] Duplicate of No. 2527.

Sample 2427 was taken from a split of the Red Ash air that ventilated the northernmost workings, which were 600 to 620 feet below the surface and had 30 miners. The Cooper-Bennett-Checker return drains workings in these beds in about half of the mine; it carried a very moderate proportion of methane. The Hillman return, taken in No. 15 slope, represents a small area of deep-lying workings in which 20 men were mining a 7-foot bed of coal. The Kidney return was from an area about a half mile square lying 120 to 280 feet below the surface and nearly all old workings. These two samples had a remarkably small methane content. A sample taken in the Red Ash workings of gas that had accumulated near the face while the brattice in the west gangway on No. 22 slope was being changed carried 18.5 per cent methane, 0.2 per cent carbon dioxide, and 16.6 per cent nitrogen. A second sample collected under similar conditions in the Ross bed just above this place carried 17.3 per cent methane, 0.10 per cent carbon dioxide, and 17.1 per cent oxygen.

DELAWARE MINE.

The Delaware mine of the Delaware & Hudson Coal Co. is in Hudson, a short distance northeast of the Pine Ridge mine. The conditions in the two mines were closely similar in most respects, but in the Delaware the coal beds are at shallower depths and are less irregular in structure. The amounts of gas varied irregularly in different parts of the mine, but some of the beds were very gaseous at certain places. Some of the returns in this mine were sampled by H. I. Smith on March 20 and 21, 1912, and were analyzed with the following results:

Results of analyses of return-air samples collected in March, 1912, from Delaware mine.

Lab. No.	Return.	Place of sampling.	Air current.		Proportion of gases in mine air.			Volume of methane per minute.
			Volume per minute.	Velocity per minute.	Methane.	Carbon dioxide.	Oxygen.	
			Cu. ft.	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cu. ft.*
2477	Ross	No. 2 gangway in No. 4 slope, Cooper return.	48,500	570	0.26	....	20.18	78
2475	Ross and Checker.	No. 16 tunnel, in Cooper bed.	31,000	500	.24	....	20.65	74
2476	do	do.[a]	....	....	.23	0.09	20.51	71
2471	Ross and Bennett.	Ross return, 400 feet from shaft.	25,000	417	.17	.08	20.81	42
2472	do	do.[a]	....	....	.19	.07	20.31	47
2480	Bennett and Cooper.	No. 5 road, 100 feet from shaft.	35,500	612	....	.03	20.33	0
2473	Five-foot, Cooper, Bennett, and Checker.	East gangway in Cooper bed, 500 feet from shaft.	46,000	766	.07	.10	20.74	32
2474	do	do.[a]	....	....	.05	.07	20.67	23

[a] Duplicate of preceding sample.

Most of the returns given above are splits which drain extensive workings. The Ross return, from which sample 2477 was taken, came from an area about one-half mile square, most of it lying 200 feet below the surface, and the bed is only 30 inches thick. The return (samples 2475 and 2476) from the Ross and old Checker workings drained about 30 acres in the Ross and 27 acres in the Checker. The air represented by sample 2471 drained the Ross workings 1 mile long by 400 to 1,000 feet wide, in part old workings, and also part of the Bennett workings, and carried little gas considering the great area of coal surface that is ventilated. The Bennett-Cooper return drained extensive workings, mostly old ones. The Bennett bed is about 140 feet and the Cooper 160 feet below the surface, and the absence of gas in the return from this large area of coal is difficult to explain. Samples 2473 and 2474 were taken from a return from a large area of the Cooper workings and a small area of recent Five-foot and Checker workings in greater part not very far below the surface. A sample of air from a face in the Ross workings, on a gangway known as "½ west," off No. 6 slope, contained 33.4 per cent methane, 0.10 per cent carbon dioxide, and 13.25 per cent oxygen.

MINES SOUTH OF WILKES-BARRE.

BALTIMORE NO. 5 MINE.

The Baltimore No. 5 mine of the Delaware & Hudson Coal Co. is near the southeastern margin of the city of Wilkes-Barre. The strata are in the long southeastern rise out of the deep central basin and present moderate dips to the north with a few local interruptions. All the beds are worked and the depth of the lowest one, the Red Ash, is 800 feet and more in places. In general, this bed gave off more gas than the others, but the variations seemingly were not related to the structure except that the emanation increased with depth. One feeder of considerable volume was observed in the roof in the Red Ash workings. There was a large influx of water in the floor below it. Several returns in this mine were sampled by H. I. Smith on March 20, 1912, which were analyzed with the following results:

Analyses of return-air samples collected in March, 1912, from Baltimore No. 5 mine.

[G. A. Burrell, analyst.]

Lab. No.	Return.	Place of sampling.	Air current.		Proportion of gases in mine air.			Volume of methane per minute.
			Volume per minute.	Velocity per minute.	Methane.	Carbon dioxide.	Oxygen.	
			Cu. ft.	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cu. ft.*
2465	Red Ash	East side return 75 feet from shaft.	83,200	440	0.08	0.07	20.63	66
2466	do	do.[a]			.07	.07	20.73	56
2467	Baltimore	First east gangway	27,300	224	.60	.06	20.68	164
2468	do	do.[a]			.56	.07	20.71	153
2469	do	West side main return	69,500	662	.35	.06	20.67	243
2470	do	do.[a]			.36	.05	20.69	249

[a] Duplicate of preceding sample.

The Red Ash return current was a single split which drained about 150 acres, in which about 120 miners were at work. The bed is 9 to 12 feet thick and although considerable amounts of gas were given off in places the total volume was small. The two Baltimore return air currents were splits off the main east and west return currents, part of which drained extensive old workings. The total volume of the Baltimore return air was stated to be 120,000 cubic feet a minute, and if this air has an average content of 0.40 per cent of methane the total emanation from that bed was 480 cubic feet a minute.

CUNNYNGHAM MINE.

The Cunnyngham mine of the Delaware & Hudson Coal Co. is in the northeastern part of Wilkes-Barre. Its chambers extend deeper into the basin than the Baltimore No. 5 workings, and some of the beds have been worked to the bottom of the basin. The mine is moderately gaseous and in it the Hillman bed begins to carry the increased amount of gas notable in this bed in a large part of the Wilkes-Barre area. The conditions in this mine were not investigated in detail, but a few samples of returns collected by H. I. Smith, March 20, 1912, were analyzed with the following results:

Analyses of return air collected in March, 1912, from Cunnyngham mine.

[G. E. Burrell, analyst.]

Lab. No.	Return.	Place of sampling.	Air current.		Proportion of gases in mine air.			Volume of methane per minute.
			Volume per minute.	Velocity per minute.	Methane.	Carbon dioxide.	Oxygen.	
			Cu. ft.	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cu. ft.*
2461	Baltimore, east	50 feet east of air shaft	47,000	470	0.11	0.03	20.62	52
2462	Do	do. [a]			.11	.05	20.62	52
2463	Baltimore, west	Air bridge over old east gangway.	42,300	445	.16	.05	20.42	68
2459	Kidney-Abbott-Hillman.	On Hillman, 500 feet from shaft.	37,900	557	.07	.07	20.62	26
2469	Do	do. [a]			.10	.05	20.67	38

[a] Duplicate of preceding sample.

The splits represented in the above samples drained various parts of the workings and the analyses show a remarkably uniform methane emanation. The total Baltimore return carried about 152,000 cubic feet of air per minute, and with an average methane content of 0.14 per cent the volume of methane would be about 213 cubic feet a minute, which is very small in view of the large extent and the depth of the workings. The Kidney-Abbott-Hillman return drains an area about a half mile square, in which the Hillman bed lies about 120 feet below the surface.

HOLLENBACK MINE.

The Hollenback mine, which is one of a group owned by the Lehigh & Wilkes-Barre Coal Co., is not far east of the center of the city of Wilkes-Barre. The workings extend under a district in which the strata are elevated and depressed in a marked anticline and syncline and present numerous minor rolls and steep dips or "faults." Several beds are worked. Considerable gas is given off in places in the deeper workings, but the rate of emanation is very irregular and the variations can not be connected with the structure. Some of the faulted zones were gaseous, but this may simply indicate that the store of gas is given off more rapidly where the coal is shattered, the aggregate amount being no greater than elsewhere.

An extensive series of samples of return air in the mine were taken by H. I. Smith in March, 1912, and the results of the tests are given in the following table:

Analyses of return-air samples collected in March, 1912, from Hollenback mine.

[G. A. Burrell, analyst.]

Lab. No.	Return.	Place of sampling.	Air current.		Proportion of gases in mine air.			Volume of methane per minute.
			Volume per minute.	Velocity per minute.	Methane.	Carbon dioxide.	Oxygen.	
			Cu. ft.	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cu. ft.*
2380	Top Red Ash	No. 4 slope, 75 feet from air shaft.	29,300	381	0.39	0.07	20.61	114
2381	Do	do.[a]			.41	.08	20.64	120
2378	Red Ash-Ross	50 feet west of air shaft	79,200	727	.65	.07	20.31	515
2379	Do	do.[a]			.59	.06		477
2377	Do	South of air shaft	37,000	475	.66	.10	20.51	244
2382	Do	50 feet from air shaft	164,300	990	.26	.07		427
2383	Do	do.[a]			.30	.10		493
2372	Baltimore	East of Baltimore air shaft.	35,200	558	.20		20.04	70
2373	Do	do.[a]			.17	.20	19.93	60
2366	Stanton-Hillman	At air shaft, Stanton	63,800	1,100	.22	.08	20.49	140
2367	Do	do.[a]			.21	.06	20.44	134
2371	Stanton	No. 15 tunnel, 400 feet from slope.	33,500	782	.15	.09	20.28	50
2374	Hillman-Kidney	Foot of Baltimore air shaft.	60,200		.14	.06	20.50	84
2375	Do	do.[a]			.27	.03	20.61	162
2368	Do	No. 22 tunnel, 700 feet from air shaft.	58,700	725	.07	.09	20.39	41
2369	Do	do.[a]			.09	.10	20.58	53

[a] Duplicate of preceding sample.

These samples of various returns in the Hollenback mine cover a moderately large proportion of the ventilation. The amount of gas given off varied in different beds and in different parts of the same bed without corresponding variations in structure or any other observed features, although the results show that there must have been considerable diversity in the conditions governing the occurrence of the gas. The Red Ash return (samples 2380, 2381) drained an area east of the hoisting shaft. Samples 2378 and 2379 represent the return from the west side of the Ross workings and a small part of the Red Ash workings, but most of the gas was from the Ross. Sample 2377 is air from the top Red Ash from tunnels 28, 12, and 9, with some east side Ross air. Sample 2383 represents all of the return from the east side workings in the Red Ash bed, which is 14 feet thick, and is moderately gaseous in places. These samples (Lab. Nos. 2377 to

2883) probably represent the total return air from the Red Ash and Ross workings, amounting in all to a volume of 1,262 to 1,372 cubic feet of methane a minute. The relations of these beds vary greatly from place to place, but in general the Ross bed is about 9 feet thick and underlain by 18 to 35 feet of "slate". The top Red Ash is 7 feet thick and the bottom Red Ash 14 feet, with 30 to 35 feet of rock between.

The return air from the Baltimore bed was mostly from old workings of moderate extent. The Stanton-Hillman return was from old workings in which the beds dip west and, together with the return from which sample 2371 was taken, represents all the air from the Stanton workings. The Hillman-Kidney return (samples 2374 and 2375) was from the workings in these beds on the lower slopes, which extend down No. 3 plane, and samples 2368 to 2369 represent the returns from upper workings in the Hillman and Kidney beds.

Some face samples were also obtained in the Ross and Kidney workings. One, which was taken in No. 36 chamber, Ross outlet, 30 feet from the face, after an explosion in which two men were fatally burned, contained 4.12 per cent methane, 1.93 per cent carbon dioxide, and 15.78 per cent oxygen. This place had formerly shown little gas. A sample was taken in No. 48 breast off No. 13 tunnel east in the Kidney bed, 40 feet from the face, where gas had accumulated overnight. The sample contained 13.2 per cent methane, 0.4 per cent carbon dioxide, and 15.1 per cent oxygen.

MAXWELL NO. 20 MINE.

The Maxwell No. 20 mine of the Lehigh & Wilkes-Barre Coal Co. was visited by H. I. Smith in March, 1912, and the return-air sampled at various places. The results of analyses were as follows:

Results of analyses of return-air samples collected in March, 1912, from Maxwell No. 20 mine.

[G. A. Burrell, analyst.]

Lab. No.	Return.	Place of sampling.	Volume of air current per minute.	Proportion of gases in mine air.			Volume of methane per minute.
				Methane.	Carbon dioxide.	Oxygen.	
			Cu. ft.	*P. ct.*	*P. ct.*	*P. ct.*	*Cu. ft.*
2529	Red Ash	West return, 50 feet from south shaft.	104,000	0.65	0.04	20.63	676
2402	Ross	No. 10 tunnel	18,400	.76	.04		294
2401	do	West airway, No. 10 tunnel	35,400	.75	.07	19.39	265
2404	Baltimore	Baltimore airway, No. 10 tunnel	24,400	.97	.06	20.32	237
2405	do	do.[a]		.95	.06		231
2408	Hillman	No. 14 tunnel to Baltimore	17,900	.80	.0[illegible]		143
2409	do	do.[a]		.87	.10	20.58	156
2406	Abbott-Kidney	No. 5 slope, west Hillman, last crosscut in chamber.	29,800	1.22	1.34	18.74	364

[a] Duplicate of preceding sample.

These scattered samples were taken in parts of the mine that were especially gaseous. The Red Ash return was a split from the northwestern corner of the Red Ash workings where about 25 miners were working. The bed is 10 to 12 feet thick and about 800 feet below sea level, or 1,400 feet below the surface. Many of the working faces liberate gas rapidly, and at times the mining has had to be suspended to let the gas drain off. The Ross return was from the deep workings to the north in which considerable amounts of gas were given off. A sample, representing air from four chambers, taken in No. 34 breast off No. 18 tunnel from a return having a volume of 115,200 cubic feet a minute, had a content of 37.40 per cent methane, 0.39 per cent carbon dioxide, 13.06 per cent oxygen, and 49.15 per cent nitrogen. Another sample from this place carried 42.77 per cent methane, 1.51 per cent carbon dioxide, and 11.11 per cent oxygen. The Baltimore return was a split from the south workings in that bed where much coal was being mined in an area a mile long by 1,200 feet wide from north to south. The bed here is 16 feet thick. The Hillman return air represents only a part of the ventilation from that bed as some of it goes out by another exit. The return air from the Abbott and Kidney beds, which was probably sampled on the crest of the main anticline, was from a large area of old workings, part of which was closed by falls and from extensive fresh workings on the anticline.

MINES NEAR NANTICOKE AND HANOVER.

AUCHINCLOSS MINE.

The relatively new Auchincloss mine of the Delaware, Lackawanna & Western Coal Co. is in the southeastern margin of Nanticoke near the center of the main basin. The strata are steeply folded and on the south side of the mine are traversed by a great "fault," or abrupt overturn, by which the lower beds are carried up several hundred feet, as shown in figure 31.

All the usual beds were being worked in this mine at the time of the author's visit, except the Red Ash which, however, had been opened to a small extent at the foot of a shaft 1,750 feet deep. The mine is gaseous, all the beds producing considerable methane, but seemingly the volume of gas had no relation to the structure, except that the Baltimore bed was especially gaseous at the steep upturn near the tunnel shown in the middle of figure 31. Feeders occur in places, but most of the gas emanation was from the working faces. One feeder observed was in the Mills bed near the bottom of a small syncline. The Baltimore workings were the most gaseous. The George bed in a place where the strata are nearly vertical reaches the surface in a railroad cut a short distance southwest of the shaft, and gas which has been flowing out of it for years would burn over an area of 10 square feet. There was said to be less than 1 per cent of methane in the upcast air from this mine which, however, carried about 200,000 cubic feet of air a minute.

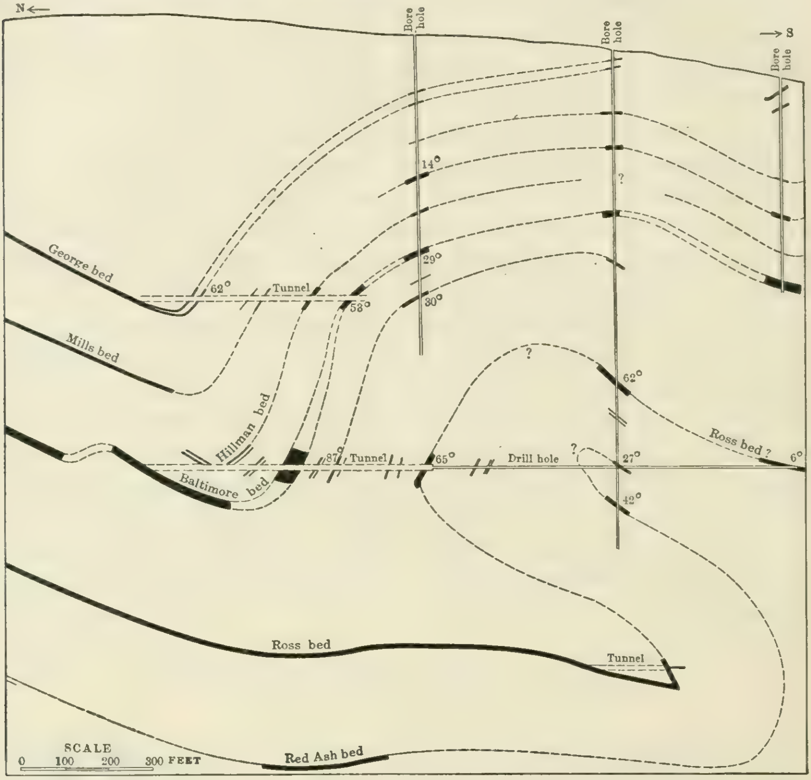

FIGURE 31.—Section through Auchincloss mine near Nanticoke, Pa., showing the great overturn in the lower beds.

Some results of analyses of return air in the Auchincloss mine, made in 1909 by H. J. Force, chemist of the company, are reported as follows:

Results of analyses of return-air samples collected October and November, 1909, in Auchincloss mine.

Shaft.	Return.	Date.	Proportion of methane in sample.	Date.	Proportion of methane in sample.
		1909	*Per cent.*	1909	*Per cent.*
No. 1	No. 3 slope	Oct. 8	0.4		
Do	Hillman	do	1.1		
Do	Upcast at shaft	do	1.2		
Do	Baltimore slope	do	1.0		
No. 2	West Mills	Nov. 26	2.1	Nov. 30	1.0
Do	East Mills	do	.4	do	.1
Do	Baltimore	do	.7	do	.8
Do	Ross slope	do	.4	do	.6
Do	Ross No. 2 west	do	.2	do	.7
Do	Forge	do	.8	do	.1

Several samples taken in March, 1912, by H. I. Smith were analyzed in the Pittsburgh laboratories of the Bureau of Mines with the following results:

Results of analyses of return-air samples collected in March, 1912, from the Auchincloss mine.

[G. A. Burrell, analyst.]

Lab. No.	Return.	Place of sampling.	Air current.		Proportion of gases in return air.			Volume of methane per minute.
			Volume per minute.	Velocity per minute.	Methane.	Carbon dioxide.	Oxygen.	
			Cu. ft.	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cu. ft.*
2503	Ross	150 feet west of No. 2 shaft	58,300	798	0.42	0.07	20.61	245
2504	do	do.[a]			.42	.08	20.41	245
2491	Baltimore-Mills	No. 23 tunnel, Mills to George.	44,500	707	2.50	.05	20.37	1,112
2494	Mills	On air bridge over east Mills gangway, 150 feet from No. 2 shaft.	37,800	485	.67	.06	20.64	253

[a] Duplicate of preceding sample.

Some of the workings in the Auchincloss mine have been very gaseous, but the emissions of gas have not been confined to any one bed. Samples 2503 and 2504 represent the air from the Ross workings tributary to No. 2 shaft, an area nearly 5,000 feet long east and west, and 2,000 feet wide north and south, and in part 900 feet below sea level. Sample 2491 was taken from a return from a relatively small area of the Mills and Baltimore workings on the steep upturn or "fault" south of the shaft. The Mills workings consisted of 17 chambers, a gangway, and an airway; the bed is about 8 feet thick. The Baltimore workings consisted of four chambers, a gangway, and an airway, and were exceedingly gaseous, there being several large blowers in the small area mentioned. The bed is 23 feet thick and the thickness of cover is about 720 feet.

It is believed that the large volume of gas from the small area was due to the crushed condition of the beds in the steep upturn and to their isolation which prevented their being drained of gas to any great degree.

The Mills return was from workings 3,000 feet long with one tier of chambers along steeply dipping beds on the south dip of a syncline. These workings lie deeper than those represented by samples 2503 and 2504. For a long time at the Auchincloss mine a comparison was made between the barometer readings and the amount of gas in the working faces as reported by the fire bosses, but no connection was found.

BLISS MINE.

The Bliss mine of the Delaware, Lackawanna & Western Coal Co. is on the mountain slope south of Nanticoke. The workings extend not only up the slope toward the outcrop but far into the deep basin to the north. There was considerable gas in parts of the Bliss mine, especially in the lower workings, where all the beds from the Mills to the Red Ash yielded much gas. Little gas was perceptible in the workings on the mountain slope. Several small feeders were observed in the Ross workings in the No. 5 slope.

The results of some analyses of samples collected in various returns in the Bliss mine, made in October and November, 1909, by H. J. Force, chemist of the company, are reported as follows:

Results of analyses of return-air samples collected in October and November, 1909, from Bliss mine.

Bed.	Return.	Proportion of methane in sample.
		Per cent.
Ross	Espy tunnel, No. 2 slope	0.0
Red Ash	Espy tunnel, No. 1 slope	.4
Ross	Espy tunnel, west Ross off No. 14 tunnel	.2
Do	Espy tunnel, east Ross off No. 14 tunnel	.0
Mills	No. 13 slope	.2
Do	Gangway 1	.1
Baltimore	No. 2 slope	.0
Do	No. 2 plane	.0
Do	No. 4 plane	.1
Ross	No. 2 plane	.2
Twin	No. 1 tunnel	.2
Ross	No. 2 plane	.1
Do	No. 3 plane	Trace.
Ross-Baltimore	No. 9 plane and No. 7 tunnel	.9
Red Ash	No. 9 slope	.4
Do	New plane off gangway F	.3

A series of samples collected by H. I. Smith on March 26, 1912, were analyzed in the Pittsburgh laboratory of the Bureau of Mines with the following results:

Results of analyses of return-air samples collected in March, 1912, in Bliss mine.

[G. A. Burrell, analyst.]

Lab. No.	Return.	Place of sampling.	Air current.		Proportion of gases in return air.			Volume of methane per minute.
			Volume per minute.	Velocity per minute.	Methane.	Carbon dioxide.	Oxygen.	
			Cu. ft.	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cu. ft.*
2496	Ross-Red Ash	West return 100 feet west of main return.	86,100	926	0.03	0.02	20.82	26
2497	Ross	East return 100 feet east of Bliss shaft.	49,280	440	.89	.07	20.60	438
2498	do	do.[a]			.92	.06	20.49	453
2499	Baltimore-Forge-Twin.	No. 3 slope	46,600	1,080	.76	.05	20.51	354
2501	do	Gangway F on bridge	68,600	980	0	.05	20.90	0
2502	Mills-Hillman	On Mills return 200 feet from shaft.	36,600	530	0	.06	20.86	0

[a] Duplicate of preceding sample.

The analysis of sample 2496 shows that the Ross and Red Ash workings in the west half of the Bliss mine gave off little methane. These workings extend over about 90 acres and although the Ross has been worked out the Red Ash is being actively mined. The Ross return air, represented by samples 2497 and 2498, was from about

400 acres of old workings east of the shaft which were exceedingly gaseous when the coal was being mined, and at the time the samples were taken were giving off a fair volume of methane. The No. 3 slope return current on Baltimore bed was a split ventilating workings 1¼ miles long by one-half mile wide in the Baltimore, Forge, and Twin beds. The Baltimore return air, sampled on the bridge on gangway F, was from a large area, about 200 acres, that lies in the south basin. The measures rise on either side and also diminished in depth to the west from a depth of 430 feet at the shaft. The bed is not gaseous, and as it lies in a high basin, much of its gas must have drained off long ago. The Mills-Hillman return was from an area three-fourths of a mile long by one-half mile wide, extending from the outcrop on the south to the fault on the north, and having only 150 feet or less of cover. The Mills workings are nearly all old and the Hillman workings were being mined by about 15 men at the time sample 2502 was taken.

TRUESDALE MINE.

The Truesdale mine, operated by the Delaware, Lackawanna & Western Coal Co., is in the south slope of the basin northeast of the Bliss mine. A large part of the workings are along the mountain slope where the coal measures are not far beneath the surface, but there are also extensive workings in the deeper basin to the north. No examination was made of the conditions in this mine, but several analyses of the return air are available, one series being taken in 1909 by H. J. Force, chemist of the company, and another March 27, 1912, by H. I. Smith, of the Bureau of Mines. Unfortunately, only part of them were taken in places where the results are comparable. The results were as follows:

Results of analyses of methane in return air in the Truesdale mine, 1909.

[H. J. Force, analyst.]

Date.	Bed.	Return.	Proportion of methane in sample.
			Per cent.
Aug. 21	Ross	No. 2 shaft, east	0.1
Do	do	No. 2 shaft, No. 1 slope	.0
Do		No. 2 shaft, west return	.3
Do	Red Ash	No. 2 shaft, top split	.4
Do	Forge	No. 2 shaft, west return	.2
Aug. 20	Ross	No. 3 slope, No. 1, west gangway	1.2
Do	do	No. 3 slope, bottom	.8
Do	do	No. 3 slope, No. 2, east gangway	.8
Do	do	No. 3 slope, No. 1, east gangway	.3
Aug. 19	Hillman	No. 6 slope	.0
Do		Holland Tunnel	.0
Do	Forge	No. 300 gangway	.3
Do	Mills	No. 5 slope	.0
Aug. 18	do	No. 3 east split off No. 1 slope	.1
Do	do	No. 3 east airway off No. 1 slope	.1
Do	do	No. 3 west, No. 1 slope	.0
Do	do	do	.2
Do	do	No. 4 west, No. 1 slope	.1

Results of analyses of return-air samples collected in March, 1912, in Truesdale mine.

[G. A. Burrell, analyst.]

Lab. No.	Return.	Place of sampling.	Air current.		Proportion of gases in return air.			Volume of methane per minute.
			Volume per minute.	Velocity per minute.	Methane.	Carbon dioxide.	Oxygen.	
			Cu. ft.	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cu. ft.*
2548	Red Ash, top and middle.	Top split, gangway, No. 1 Tunnel to mountain fan.	34,900	513	0.00	0.05	20.64	0
2549	do	do.[a]			.01	.08	20.31	3
2552	Ross, top Red Ash.	Main return to No. 1 shaft on Ross.	214,500	1,153	.95	.06	20.01	2,037
2553	do	do.[a]			.35	.04	20.82	751
2550	Ross, top and bottom.	Under Ross gangway, No. 1 Tunnel	39,000	502	.01	.05	20.72	4
2554	Ross - Red Ash - Twin.	Ross No. 2 return, 150 feet from shaft.	122,900	945	.36	.07	20.79	443
2555	do	do.[a]			.34	.08	20.56	418
2556	Baltimore-Forge	On Forge, 120 feet from shaft.	66,800	903	.23	.04	20.67	154
2557	do	do.[a]			.23	.08	20.78	154
2558	Hillman-Forge	No. 6 slope airway between No. 1 east and No. 2 east air shafts.	124,300	1,462	.56	.05	20.54	696
2559	do	do.[a]			.62	.04	20.78	771
2546	George-Mills	Near No. 1 slope fan (in doorway).	135,500	1,316	.50	.05	20.66	675
2547	do	do.[a]			.50	.04	20.75	675

[a] Duplicate of preceding sample.

The Red Ash workings on the mountain slope are almost free from gas, owing to its escape through the thin cover. The area is large, however, extending 3,500 feet along the slope and nearly one-half a mile north from the outcrop, much of the coal being worked out. The returns from the deeper workings carry much methane, especially the large main Ross return to No. 1 shaft. This return ventilates the No. 3 slope section, which extends more than a mile down the steep dip and three-fourths of a mile laterally, comprising the Ross workings—partly old, partly new—and small new workings in the top Red Ash bed. Two samples taken at the same time, however, varied greatly in their methane content, one showing that the return carried 2,037 cubic feet a minute, the other 751 cubic feet.

Samples 2554 and 2555 were taken from a split of Ross air which ventilated workings in the Ross, Red Ash, and Twin beds in a steep dip west of the No. 2 shaft. Sample 2550 was taken from the same return but in air from Ross workings only, the small methane content of which appears to indicate that the large volume of methane shown by samples 2554 and 2555 came almost wholly from the Red Ash or Twin beds.

The return from the Forge and Baltimore workings ventilated an area of about 200 acres in each bed, all near the outcrop. The Hillman and Forge return represented by samples 2758 and 2759 ventilated a narrow area 2,000 feet long near the outcrop, and the increased amount of methane in it was due to the gaseous character of the Hillman coal. The George and Mills return also carries much gas. The area, about 200 acres, drained by air represented by sample 2546, is on the Truesdale slope; there are many synclines and anticlines. Mining in the Mills bed was confined to robbing pillars, but the George workings were all in fresh coal and were very gaseous in places.

MINES BETWEEN LUZERNE AND AVONDALE.

Coal-mine workings extend almost continuously along the north dip of the coal measures from Luzerne through Kingston to and beyond Avondale. Only a few of these mines were investigated, however, and the only one tested in detail was the Lance at Plymouth, as described on previous pages. In the middle of March, 1912, H. I. Smith collected samples of some of the returns in the Pettebone, Kingston, Plymouth No. 2, Nottingham, Dodson, and Avondale mines.

HARRY E. MINE.

The workings of the Harry E. mine extend from the mountain slope north of Luzerne southeast to Wyoming Avenue, and are all on the north slope of the main basin.

Most of the especially gaseous parts of the Harry E. mine were in the lower workings toward Wyoming Avenue, where the dip has carried the beds to a considerable depth. Here the Ross and Red Ash beds yielded much gas, both in feeders and in a general emanation, especially from fresh working faces. The Pittston bed which was not extensively worked is less gaseous than the others. The Eleven-foot workings, which had been extended down the dip to within a half mile of Wyoming Avenue were not very gaseous. The Red Ash bed, which averages about 8 feet thick in this mine, is overlain by porous sandstone that carries considerable gas, possibly derived from the coal. In a tunnel it was found that this sandstone was so gaseous that the methane could be lighted in the drill holes. A sample of the fresh rock, broken and sealed in the mine, was sent to R. T. Chamberlin, of the United States Geological Survey, who found that the methane content was only 0.013 of 1 per cent. Doubtless a considerable proportion of the gas content escaped from the rock before it was sealed. The gas extracted by keeping the sample 21 days in a vacuum had the following composition:

Composition of gas in sandstone rock.

	Per cent.
Methane	4.2
Carbon dioxide	1.9
Air	70.0
Nitrogen (excess over air)	23.7

PETTEBONE MINE.

The Pettebone mine of the Delaware, Lackawanna & Western Coal Co. is in the center of the main basin of the coal field, where the general synclinal structure is complicated by a sharp parallel anticline or "fault." All the coal beds are present, the Red Ash being about 1,150 feet below the surface near the center of the basin. There are numerous small crumples in the mine, and some of these have been especially gaseous. In mining the most methane was found in the Hillman bed, as at the Dorrance and other mines in the district. The Red Ash and Cooper beds contain considerable methane, but the Ross yielded very little. The greatest amounts of gas are given off in the deeper part of the basin, near the river.

The author found much methane in many Hillman headings, not only in disturbed or flexed areas, but also in places where the coal was lying practically level. One series of strong "blowers" was found in a syncline adjacent to a steep upturn in which the beds rise 78 feet, the gas coming through the rock floor from the coal below.

A special series of tests for methane in some of the returns was made by the company on August 17, 1909, the results of which have been reported as follows:

Results of analyses of methane in return air, Pettebone mine, August 17, 1909.

Return.	Shaft.	Proportion of methane in return air.
		Per cent.
Red Ash	No. 2 shaft	1.0
Cooper, south side	No. 1 shaft	.6
Baltimore	do	.2
Five-foot	do	.6
Hillman	do	1.5
Skidmore	No. 2 shaft	.1

A few special samples of return air were taken by H. I. Smith in the Pettebone mine on March 14, 1912, and analyzed in laboratories of the Bureau of Mines at Pittsburgh, with the following results:

Analyses of return-air samples collected March, 1912, from Pettebone mine.

[G. A. Burrell, analyst.]

Lab. No.	Return.	Place of sampling.	Air current.		Proportion of gases in mine air.			Volume of methane per minute.
			Volume per minute.	Velocity per minute.	Methane.	Carbon dioxide.	Oxygen.	
			Cu. ft.	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cu. ft.*
2388	Red Ash	East return, 300 feet from shaft.	27,400	669	0.36	0.05		99
2392	Bennett-Cooper	25 feet east of No. 1 shaft.	39,600	900	.48	.06		190
2393	do	do.[a]			.51	.04	19.78	202
2390	Five-foot-Cooper	Air bridge, 100 feet from shaft.	29,900	398	.38	.08		114
2391	do	do.[a]			.45	.05		134
2386	Five-foot	East of shaft No. 1	37,900	903	.97	.05		368
2387	do	do.[a]			1.01	.05	20.55	383
2384	Hillman-Kidney	On Hillman, 50 feet west of shaft No. 1.	59,700	905	.35	.05	20.76	209
2385	do	do.[a]			.73	.05	20.50	440

[a] Duplicate of preceding sample.

These samples represented only parts of the ventilation of the mine. The east Red Ash return was from old workings north of the shaft in an area nearly a mile long and lying over 1,100 feet deep in places. The Bennett-Cooper return current was a split from about 70 acres of old workings north of the shaft. The Five-foot-Cooper return ventilated a large area of workings, mostly old, and about 20 fresh places in the Five-foot bed. The intake air was a split which first ventilated the Five-foot workings and then the Cooper. The Five-foot return air was a single split ventilating about 40 acres of live workings north of the shaft and carried increased amounts of gas because fresh coal was being extensively mined. The Hillman-Kidney return was from live workings south of the shaft in an area of 40 acres and the increased amount of methane was probably due to the amount of fresh coal exposed.

KINGSTON NO. 4 MINE.

The Kingston No. 4 mine is one of the large double-shaft mines of the Kingston Coal Co., situated on the slopes west of Kingston. At the time of the author's visit the workings had been extended far up the mountain slope to the north and under the valley flats to the south. All the beds were being worked, some more extensively than others, and there were wide areas of old workings. Methane is given off at many places, but the amount varies greatly from time to time and from place to place in the same bed. In general the strata have a uniform dip to the southeast, and although structural irregularities occur at intervals, they are not large, and the workings at these places have not been especially gaseous. The author did not examine the conditions in this mine, but on March 7 and 9, 1912, H. I. Smith collected samples in some of the returns, which were analyzed with the following results:

Results of analyses of return-air samples collected in March, 1912, from Kingston No. 4 mine.

[G. A. Burrell, analyst.]

Lab. No.	Return.	Place of sampling.	Air current.		Proportion of gases in return air.			Volume of methane per minute.
			Volume per minute.	Velocity per minute.	Methane.	Carbon dioxide.	Oxygen.	
			Cu. ft.	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cu. ft.*
2344	Red Ash..........	20 feet from No. 4 air shaft.	45,500	510	0.36	0.12	20.06	164
2345	.....do............	.....do.[a]...............	....	....	.30	.05	20.09	137
2360	Cooper............	Near No. 4 air shaft.....	24,500	490	.04	.14	19.86	10
2361	.....do............	.....do.[a]...............	....	....	.06	.16	19.99	15
2354	Lance.............	Near upper bridge on No. 6 slope.	47,000	627	.13	.08	20.54	51
2353	.....do............	At lower bridge over No. 6 slope.	67,100	1,100	.20	.07	20.25	134
2357	Orchard...........	150 feet west of No. 3 shaft.	56,500	1,344	.01	....	20.54	6
2358	.....do............	10 feet south of No. 6 air shaft.	83,500	1,325	.40	.06	20.27	334
2359	.....do............	.....do.[a]...............	....	....	.38	.06	20.33	317

[a] Duplicate of preceding sample.

These samples represented only parts of the returns in certain beds and detached sections of the mine, but they afford some interesting comparisons. The Red Ash return air was one split from a large area north of the shaft in which the beds rise on the mountain slope. The workings were all old and largely closed by falls, but many parts were filled with culm flushing, which may account for the large emanation of methane. The sample of air from the Cooper returns was from workings of considerable extent, mostly old, but seemingly yielding little methane. The air in the Lance returns was represented by two parts of one of the main splits ventilating about 100 acres of workings that extended south into the basin. Part of these workings were old, but the deepest ones were fresh and gave off considerable gas. The Orchard return current, which was sampled 150 feet west of No. 3 shaft, was a split draining about 200 acres of workings, some of which were live and some old and mostly caved. The coal is 4½ feet thick, and as the bed is not far below the surface in this district it has lost most of its gas. The sample taken near No. 6 air shaft was from a split from about 100 acres of workings which extend far down into the basin south of the shaft. The upper part of the workings was old, the lower part was fresh workings which lie far beneath the surface, and was very gaseous.

PLYMOUTH NO. 2 MINE.

The Plymouth No. 2 mine, which belongs to the Delaware & Hudson Coal Co., is a short distance east of the Lance mine, but its workings lie higher on the north slope of the basin than most of the Lance workings. The strata dip at low angles to the southeast and rise to the outcrop on the mountain slope to the north. Considerable gas is found in places, especially in the Red Ash bed. The roof is gaseous in places and whenever it cracks considerable gas is given off. A series of samples were taken in the returns of this mine by H. I. Smith on March 22 and 23, 1912, and were analyzed with the following results.

Results of analyses of return-air samples collected in March, 1912, from Plymouth No. 2 mine.

[G. A. Burrell, analyst.]

Lab. No.	Return.	Place of sampling.	Air current.		Proportion of gases in return air.			Volume of methane per minute.
			Volume per minute.	Velocity per minute.	Methane.	Carbon dioxide.	Oxygen.	
			Cu. ft.	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cu. ft.*
2513	Bottom Red Ash..	No. 4 gangway, No. 6 plane, 700 feet from No. 5 shaft.	29,300	610	0.17	0.08	20.81	50
2507	Bottom and top Red Ash.	100 feet from No. 2 shaft.	103,600	1,114	.22	.03	20.69	280
2511	Cooper-Five-foot..	Gangway, 150 feet from No. 2 shaft on Cooper.	36,300	595	.10	.04	36.30	36
2515	Stanton...........	400 feet from No. 2 shaft.	45,400	921	.07	.16	20.26	32
2517	...do..............	First west gangway on No. 6 slope, 450 feet from No. 2 shaft.	20,600	267	.00	.04	20.91	0
2519	Kidney...........	20 feet from fan..........	26,700	445	.02	.03	20.58	5
2520	.....do.............	.....do.[a]................	....	....	.01	.03	20.68	3
2509	Snake Island-Abbott.	On Abbott 75 feet from No. 1 shaft.	27,300	290	.07	.03	20.82	19
2510	.....do.............	.....do.[a]................	....	....	.07	.03	20.76	19

[a] Duplicate of preceding sample.

Sample 2507, taken 100 feet from No. 2 shaft, represents the return from a large part of the workings in the Red Ash bed. The methane emanation was of moderate volume for many of the workings were old and some were only moderately deep as the beds rise rapidly to the north up the mountain slope. The Cooper Five-foot return air was a split from the deeper workings in the Cooper bed, about 70 acres in extent, and about 45 acres of up-slope workings in the Five-foot bed. The Stanton return air was in two splits; the first from an area that sloped upward from the shaft and the second, containing no methane, was from deeper workings of moderate extent and about 300 feet below the surface. The Kidney return was from about 20 acres of live workings which were 120 feet below ground, and the Snake Island-Abbott return was from workings similar in extent but somewhat deeper.

Some face samples taken in the return split from the top Red Ash bed contained 52 to 16.60 per cent of methane, the sample containing 16.60 per cent being taken in the No. 2 west gangway off the No. 9 slope.

DODSON MINE.

The Dodson mine in Plymouth is on the north slope of the basin, the workings extending down nearly to its center. The author made no investigation of the conditions in this mine but according to report the mine is less gaseous than the neighboring Lance and Nottingham mines. On March 5, 1912, H. I. Smith collected samples of return air from three returns in this mine which were analyzed with the following results:

Analyses of return-air samples collected in March, 1912, from the Dodson mine.

[G. A. Burrell, analyst.]

Lab. No.	Return.	Place of sampling.	Air current.		Proportion of gases in return air.			Volume of methane per minute.
			Volume per minute.	Velocity per minute.	Methane.	Carbon dioxide.	Oxygen.	
			Cu. ft.	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cu. ft.*
2340	Red Ash-Ross	Tunnel from Five-foot to Bennett workings.	50,400	600	0.09	0.05	20.90	45
2343	Hillman-Orchard	Entry, regular Hillman return.	62,100	1,090	.05	.27	19.97	31
2338	do	Head rock plane from Orchard to Hillman workings.	38,500	876	.10	.40		38
2339	do	do.[a]			.07	.42	18.96	27

[a] Duplicate of preceding sample.

These returns carry only small volumes of methane notwithstanding the fact that they drain extensive workings where there is much mining; the same beds in a similar position in the Lance mine just east carry much larger amounts. These results show the variability in methane occurrence, which in this area is not due to difference in structure or depth, or character of cover.

NOTTINGHAM MINE.

The Nottingham mine of the Lehigh and Wilkes-Barre Co. is in the western part of Plymouth. It was visited by H. I. Smith on February 23, 1912, and several samples of air were taken, which were analyzed with the following results:

Results of analyses of return-air samples collected in March, 1912, from Nottingham mine.

[G. A. Burrell, analyst.]

Lab. No.	Return.	Place of sampling.	Air current.		Proportion of gases in return air.			Volume of methane per minute.
			Volume per minute.	Velocity per minute.	Methane.	Carbon dioxide.	Oxygen.	
			Cu. ft.	*Feet.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cu. ft.*
2181	Red Ash	75 feet east of No. 2 fan	52,400	624	0.41	0.18	19.65	215
2183	do	East of No. 1 fan	63,300	713	.49	.24	19.74	310
2184	do	Right slope, 150 feet from No. 2 air shaft.	159,000	914	.73	.18	20.48	1,161
2185	do	do.[a]			.66	.14	20.42	1,049
2176	Ross	East and west returns at bottom of No. 2 air shaft.	44,200	502	1.59	.03	20.31	703
2174	do	100 feet south of No. 2 air shaft.	57,800	359	1.14	.07	20.28	659
2175	do	do.[a]			1.14	.05	20.18	659

[a] Duplicate of preceding sample.

The Red Ash return-air samples were taken from parts of the extensive Red Ash workings, large areas of which are very old. Probably the total emanation of methane from the Red Ash bed in this mine is more than 2,500 cubic feet a minute. The Ross returns represent a large area of deep workings, some of which were in active operation at the time of sampling.

AVONDALE MINE.

The Avondale mine of the Delaware, Lackawanna & Western Coal Co. is on the north bank of the Susquehanna about halfway between Plymouth and Nanticoke. The workings extend far to the south under the river flats and also under the mountain slopes to the north. In the deepest workings the Red Ash bed is more than 400 feet below sea level, or about 900 feet below the river. The lower workings have always been gaseous and considerable gas has been found in places on the higher slopes.

A few years ago part of the deeper workings suffered a serious squeeze, and then, partly on account of the fracturing and partly on account of ventilation being impeded, a large amount of gas accumulated in the lower levels. A series of samples of return air from workings in the affected territory was taken by the company July 24, 1909, and analyzed by H. J. Force, chemist of the company, with the following results:

Methane in samples of return air from workings affected by squeeze.

	Per cent.
Red Ash bed, No. 6 slope	1.0
Ross bed, No. 5 slope, west side	1.6
Ross bed, No. 5 slope, east side	1.2

On March 15, 1912, the mine was visited by H. I. Smith, who collected two samples of part of the return air from Red Ash workings under the flats, the workings being mostly old and about 100 acres in extent. The return on No. 2 slope in the Red Ash bed, 600 feet from the fan, was passing 117,600 cubic feet of air a minute, which carried 0.79 per cent methane, or 940 cubic feet a minute. This sample contained 0.10 per cent of carbon dioxide. A sample taken in No. 7 air slope, 300 feet from No. 1 Ross fan, where the air volume was 29,200 cubic feet a minute, contained 0.17 per cent of methane and 0.07 per cent carbon dioxide.

METHANE FROM CULM.

It is a remarkable fact that culm flushed into the mine workings gives off methane, sometimes in sufficient volume to be dangerous. The gas escapes not only while the culm is wet, but also after the water has drained off. Much of the culm that is used for filling has been lying in great heaps for 20 years or more. Culm consists of coal mixed with more or less "slate" and lately is being utilized by crushing and sorting out the coal of saleable size. The refuse from this process, consisting of a mixture of fine coal, "slate," and dirt, is flushed into the old mine chambers, so that the pillars can be removed. At most mines the fresh waste from the breakers is also treated by the same process, so that it is not weathered like the material on the old culm heaps.

No investigation was made as to the relative amounts of gas in the old culm and the new waste as now flushed into the mines, but according to reports all the material gives off some methane. This fact is in accord with the chemical investigations of coal samples described in another part of this report for these were found to give off gas for several years after they had been collected.

PRESSURE OF GAS IN THE ANTHRACITE FIELD.

It is evident that the gas is under great pressure in the coal in parts of the anthracite field, but no special tests were made to determine the pressure. Some of the gas blowers and feeders show much force, and in many places the coal is thrown from the face in such a manner as to indicate high pressure.

The only pressure observation made was at a hole bored 45 feet from the upper Ross workings into the top of the lower Ross bed in the Maxwell mine at Ashley, which had tapped gas in large volume. This gas was held by a valve placed in a casing which had been cemented tightly in the rock. The author had a steam gage attached to the valve, and the next day found that it registered 45 pounds to the square inch.

GAS IN BORE HOLES IN THE ANTHRACITE FIELD.

There is no more direct proof of the variation in the amount of gas in the coal or at least of the rate of emanation than the varying amounts of gas given off by bore holes. Thousands of holes have been sunk in the anthracite area, and although most of them do not give off much gas, others have tapped strong flows. Occurrences of this character are not related to depth or structure of the coal, although in some cases the gas comes from a bed or district known to be gaseous. Some of these holes are sunk in the mines from workings in one bed to other coal beds.

One noteworthy instance of this character is in the Maxwell mine at Ashley where, as described above, a hole from the upper Ross workings to the top of the lower Ross bed struck a large volume of gas which had a pressure of 45 pounds to the square inch. In many cases the gas flow is short lived, but in others it continues for a long time. In the Lance mine a 10-inch hole from the Stanton workings to the Red Ash bed developed a flow of gas estimated at 1,000 cubic feet a minute, and blower gas has been used for fuel in this mine.

In the Holden mine at Taylor a bore hole from the Clark bed through the Dunmore beds yielded a large flow of gas, which at one time was piped to the surface and used for fuel and in the Stanton mine near Wilkes-Barre a feeder from the Hillman (?) bed was piped to a pump house and used for illumination for many years. A bore hole from the Clark workings to the Dunmore bed in the Pancoast mine near Scranton also yielded a large volume of gas. Gas was found in borings from the surface through the coal measures at Hudson, and has been flowing out of the casing for several years; when it is ignited the high flame indicates a large volume.

Some of the bore holes through the valley filling into the coal measures near Wilkes-Barre and elsewhere have tapped gas in considerable volume. One such hole is a few rods southeast of Luzerne Station, where a pipe from a 98-foot hole sunk 11 feet into shale has been giving off gas for years. A sample of this gas was collected and analyzed by Chamberlin [a] with the following results:

Results of analysis of gas from bore hole near Luzerne Station.

	Per cent.
Methane	91.31
Olefins	.49
Carbon dioxide	1.59
Carbon monoxide	.04
Hydrogen	.82
Air	1.10
Nitrogen (excess)	4.65
	100.00

A sample of gas from a bore hole at the foot of the No. 11 slope in the Dorrance mine was also collected on September 4, 1908, and analyzed by Chamberlin with the following results:

Results of analysis of gas from bore hole in Dorrance mine.

	Per cent.
Methane	90.65
Olefins	.09
Carbon dioxide	.05
Carbon monoxide	.00
Hydrogen	.77
Air	2.73
Nitrogen (excess)	5.71
	100.00

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[a] Chamberlin, R. T., Notes on explosive mine gases and dusts, with special reference to explosions in the Monongah, Darr, and Naomi coal mines: Bull. 26, Bureau of Mines, p. 31; Reprint of U. S. Geol. Survey Bull. 383.

GAS CONDITIONS IN ANTHRACITE FIELD COMPARED WITH THOSE IN OTHER AMERICAN MINES.

Little information is available as to the amount of methane given off in mining coal in the United States, but in the course of investigations by the members of the Bureau of Mines return-air samples have been obtained at several mines. Analyses of some of these presented in the following tables are of interest for comparison with the analyses given on the preceding pages. All the analyses were made by G. A. Burrell, chemist of the bureau.

Analyses of part of return air from mine at Roslyn, Wash.

[Samples collected by H. M. Wolflin.]

Lab. No.	Return.	Volume a minute.	Velocity a minute.	Methane.		Carbon dioxide.	Oxygen.	Nitrogen.
				Per cent.	Cubic feet a minute.			
		Cu. ft.	*Feet.*			*Per cent.*	*Per cent.*	*Per cent.*
1431	Main	39,260	755	0.39	153	0.07	20.48	79.06
1434	Seventh east split	4,450	100	1.28	57	.07	20.36	78.29
1436	Eighth west	1,592	70	1.33	21	.06	20.25	78.36

This mine is considered gaseous, but the methane volume in the main return would be regarded as moderate in the anthracite region.

Methane in various parts of Ellsworth 3 and 4 mines in Pittsburgh coal bed, Washington County, Pa.

[Samples collected by Dunbar, Mar. 3, 1911.]

Place where sample was taken.	Methane.	
	Cubic feet a minute.	Per cent.
Entries at shaft	160	0.19
Main return	203	.70
Left entry, working face ahead of air		1.38
Left west main entry, 30 feet beyond air		1.80
South split face	223	.95
West split face	38	.17
West main split	152	.68
Split D face	52	.39
Northeast split, C face	207	.94
West main split	165	1.49
North split, C face	35	.32
Northeast split, C face	261	.75
East main parallel entry	17	.10
9th west split, off A face	22	.14
C face, south split	308	.95
Back of shaft 3	223	.71
D face, west split	27	.34
C face, northeast split	22	.10
Main return, west of shaft 4	450	.75
Return to Tombaugh air shaft	321	.85

These methane determinations show great variation in the emanation in different returns and from a number of working faces. The variations are not related to the amount of coal mined, and indicate that the same bed of coal is giving off much more gas at one place than another. The bed is thick, seemingly uniform in character, and lies nearly horizontal.

In some mines there is no appreciable trace of methane in the returns. One instance of this is in the Bevier coal field in Macon County, Mo., where two samples of the return air were collected by H. I. Smith, April 1, 1911. One return 200 feet south of the shaft with a volume of 15,732 cubic feet a minute contained no methane and 0.39 per cent of carbon dioxide. Another return with 21,610 feet of air was also free from methane and contained 0.44 per cent of carbon dioxide.

SOME FEATURES OF FIRE-DAMP EXPLOSIONS IN THE NORTHERN ANTHRACITE FIELD.

Explosions of small bodies of fire damp frequently occur in the deeper mines in the anthracite region, many of them with fatal results. According to the reports of the Department of Mines of Pennsylvania 245 men were killed by gas explosions in the northern anthracite basin in the 10 years from 1899 to 1909, an average of nearly 25 men a year. It is not the purpose of this report to take up the cause and history of these accidents, but a few statements will be given relative to the manner in which the fire damp occurs.

The gas explosions take place under a great variety of conditions, but most of them are caused by taking an open light into a place where there is an unexpected body of fire damp. Generally such accumulations are at the working faces but sometimes are in old workings. In many instances, however, the existence of gas is known but warnings are disregarded and by striking a match, opening a safety lamp, or carrying an open light the gas is ignited.

Sometimes when new workings break through into old ones a body of gas is encountered. The temporary lessening of air currents by leaving doors open or breaking down the brattice by blasts is a frequent cause of the accumulation of gas at the face, and then, when circulation is restored, the accumulation of gas is carried out into the workings and perhaps ignited. Gas given off by a run of coal has caused many an explosion, for a large body of broken coal may give off a large volume of gas quickly. There have been some noteworthy outbursts of this class in those sections of the anthracite region where the beds dip steeply. Many blowers and feeders are opened where little gas was given off before, and the silent emission of gas from the face or roof sometimes fills a chamber very quickly. It is a matter of daily observation that although the fire boss may find no gas in the working place in his early morning inspection, by the time the miners arrive gas has accumulated to a dangerous extent, even though the ventilation is carried reasonably close to the face. Gas often accumulates when the air is still in old workings and generally in roof cavities, where a man climbing over the pile of fallen material with an open light in his cap may ignite it.

A few quotations from records of ordinary explosions are here given to illustrate some of the conditions of occurrence of unexpected bodies of fire damp.

(1) Regarding an explosion in which 7 men were fatally burned and others more or less injured, a district mine inspector stated that he "made a thorough investigation as to the cause of the explosion but could find none. The ventilation is good but it may be that some doors were allowed to remain open on the day of the accident."

The jury examined the place and finding no evidence of cause, stated in the verdict that the mine was properly managed, the ventilators were good and the mine laws strictly complied with in every particular. The gas accumulated very rapidly in certain chambers but the cause of this accumulation is unknown. It was ignited by an open lamp carried by a man who had no expectation of encountering the gas.

(2) * * * miner fatally burned by gas. He turned to the face of his breast after firing a blast which cut a feeder of gas and the gas was ignited by an open light on his head.

(3) * * * miner fatally burned by gas. He fired a blast in the face of the breast which broke the brattice down. He kept on working at the face and gas accumulated, which in a short time was ignited by his open light.

(4) At the —— colliery a small explosion of gas in a chamber in the Ross bed killed one man, burned another one somewhat, and caused a fire that suffocated 8 other men. The chamber was driven about 400 feet on a 5 per cent dip to a point where there is an abrupt upturn. The coal here is greatly shattered and apparently gave off a puff of gas causing the explosion. Very little gas was made driving to this point.

(5) The chamber was found free of gas by the fire boss in his morning round. Later a rock fall broke the brattice and cut off air from the face. A miner climbed over the fall with naked light and ignited a small body of gas which had accumulated in the meanwhile. He was fatally burned by the explosion.

(6) —— was fatally injured in the Five-foot vein. He was driving a crosscut into an abandoned chamber. He fired a blast and evidently broke through and then went in with naked light to see what the shot had done. When near the face he ignited the gas.

(7) Miner killed by explosion in ——— mine. He had been working in a chamber about 40 feet above the gangway, and ignited gas that had accumulated while he was trying to set off a blast that would not go off. Meanwhile he left open the door controlling the ventilation.

(8) An explosion in the Cooper bed killed 6 men. The place was reported free from gas in two trips of the fire boss. In the afternoon a miner engaged in driving a line chamber fired a blast in the face which caused an explosion, killing him and 5 other men who were within 300 feet.

(9) At ——— mine someone set fire to some feeders in an old chamber. An hour later while inspecting the place there was an explosion which killed 2 men. In this same mine later in the day a man returned to his face after an absence of a half hour and in lighting a match ignited gas that burned him fatally. On another occasion in this mine a man ignited gas by opening his safety lamp and was killed by the explosion.

EXPLOSIVE GAS IN MINES IN THE SOUTHERN PART OF THE ILLINOIS COAL FIELD.

INTRODUCTION.

In the winter of 1912 an investigation was made by the Bureau of Mines of some of the conditions under which gas occurs in the principal mines in a part of the Illinois coal field. The work was done under a cooperative agreement with the State geological survey and the department of mining engineering of the University of Illinois.[a] The region selected was the part of the field lying south of latitude 38° and extending from Murphysboro on the west to Eldorado on the east. The outcrop zone of the coal was the southern limit. This district is 50 miles long and about 18 miles wide, its area thus being nearly 900 square miles. Nearly all the mines in this area were inspected as regards the amount and the mode of occurrence of gas and in 56 of them samples of the return air current were taken to ascertain the volume of gas given off. In some of the mines the total returns were sampled; in others, the returns from different workings were collected separately; and in a number of mines the sampling was repeated several times so as to check results and determine whether varying conditions caused related variations in the volume of gas. Tests were also made of the pressure of the gas in the solid coal by inserting iron tubes into the face, suitably tamping them, and reading the pressures on a gage. In some mines the volume of gas in the coal was determined at the holes.

GENERAL FEATURES OF THE COAL MEASURES IN SOUTHERN ILLINOIS.

DISTRIBUTION AND RELATION OF THE COAL BEDS.

Coal-bearing strata underlie more than two-thirds of Illinois, and the same field, the central, extends far to the eastward in Indiana. The coal measures are estimated to have a total thickness of 2,200 feet and in places there are several thick beds of coal in the succession. However, a thickness of 700 feet of strata at the bottom of the coal measures is not known to contain any coal over 2 feet thick. The general structure is that of a shallow basin with low dips and very few flexures or fractures of the strata.

Near the middle of the Illinois basin the lower coal beds are in places 2,000 feet or more below the surface. Near latitude 35° they lie 400 to 600 feet deep but the gradual rise to the south brings them to the surface in an outcrop zone passing near Murphysboro, Carbondale, Marion, and Harrisburg. The geology and other features of the district treated in this bulletin have been described by DeWolf,[a] by Savage and Shaw,[b] and by others. A brief résumé of the principal facts is presented here because it will be serviceable in showing the conditions under which the coals occur.

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[a] For scope and purpose of investigation see Preliminary report on organization and methods of investigations: Illinois Coal Mining Investigations, cooperative agreement, 1913, 71 pp.

STRATIGRAPHY.

There are three workable coal beds underlying the region, all in the Carbondale formation, which has a thickness of 250 to 300 feet. The top of this formation is the Herrin bed (No. 6); from 90 to 140 feet below is the Harrisburg coal (No. 5), and at the base is the Murphysboro coal (No. 2).

A typical section of the Carbondale formation as given in the record of a bore hole in the western part of the Herrin quadrangle is as follows:

Record of bore hole in Carbondale formation, Herrin County, Ill.

	Feet.
Coal No. 6 (Herrin bed)	8½
Underclay	1
Limestone	6
Shale	14
Limestone	3
Slate, black	4½
Coal No. 5 (Harrisburg bed)	4½
Shale	58
Limestone	1
Shale	3½
Coal	2
Underclay	10½
Shale, sandy	22
Sandstone	25
Shale	10
Limestone	1
"Slate"	3
Coal	½
Underclay	2½
Shale, sandy	5
Sandstone	23
Shale	24½
Coal (top Murphysboro bed?)	1⅚
Shale	20½
Coal (lower Murphysboro bed?)	2¼
Shale and sandstone of Pottsville age.	

Above the Carbondale is the McLeansboro formation which underlies the surface deposits in a wide area extending far north from the outcrop of the No. 6 coal. At its base is a gray shale or shaly sandstone that lies on the No. 6 coal and varies from 15 to 110 feet thick, the average of 120 records being 64 feet. In most of the region, especially in the eastern part of Williamson County, the black shale of the roof over the coal is capped by 3 to 4 feet of limestone. About 105 to 110 feet above the No. 6 coal (Herrin) is a fairly persistent coal bed, 1½ to 2 feet thick, in sandy shale and sandstone, and other thin beds of coal occur higher up. The Herrin coal varies from 6½ to 14 feet thick, the average of 130 records being

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[a] DeWolf, F. W., Coal investigations in the Saline-Gallatin field, Illinois, and the adjoining area: Illinois Geol. Survey Bull. 8, 1907, pp. 211-230, and U. S. Geol. Survey Bull. 316, 1907, pp. 116-136; Coal investigations in Saline and Williamson Counties, Illinois: Illinois Geol. Survey Bull. 8, 1908, pp. 231-245.

[b] Shaw, E. W. and Savage, T. E., Description of the Murphysboro and Herrin quadrangles: U. S. Geol. Survey Folio 185, 1912, 15 pp.

9½ feet; at Galatia the average is 6 feet in most places. Eighteen to 30 inches above the base of the bed there is an impure layer known as "blue band," which is a characteristic feature of this bed. This layer is generally nearly 2 inches thick, but near the western outcrop zone it thickens to 6 to 11 inches.

The Harrisburg or No. 5 coal, which underlies the area from Jackson to Saline County, is 5 to 7 feet thick in the mines in Saline County; the average of 40 measurements in the Herrin district is 4⅓ feet. It is a solid body of massive coal of moderate hardness with few impurities.

It is overlain by a member of black shale, thin limestone, and sandstone, which separates it from the Herrin coal. The thickness of this intervening series is 37 to 40 feet in the Herrin district and westward, but in Saline County it varies from 100 to 140 feet and the succession of beds also varies considerably.

The Murphysboro or No. 2 coal lies about 250 feet below the Herrin coal with sandstone and shales intervening. The coal varies in thickness from 1 to 6 feet and in the greater part of the district is in two beds, which are separated by a body of shale. In the southwestern part of sec. 32, T. 8 S., R. 2 W., the intervening shale is 35 feet thick, whereas in the southeastern part of the section it is only 4 to 5 feet thick. The coal is capped by 20 to 40 feet of clay and shale, which is overlain by 15 to 45 feet of sandstone that has been designated as the Vergennes member of the Carbondale formation. Coal No. 2 is extensively worked about Murphysboro but it is not mined in the region east where it is not far below the lower workings of many mines. At the Gus Blair mine the No. 2 bed consists of 11 inches of top coal, 3 inches of bone, 23 inches of shale and concretions, and 46 inches of coal on a sandstone floor. In a bore hole at Murphysboro the coal in the bed is 6½ feet thick, but to the northward it thins and is absent in places.

STRUCTURE.

As one purpose of the investigation was to ascertain whether or not occurrences of gas in coal have any relation to structure, special consideration was given to the structural features of the coal beds in southern Illinois. A map (Pl. VII) was compiled from maps by Shaw, Savage, De Wolf, and Cady, to show the configurations of the coal beds, and on it are represented also the depths to coal, the lines of outcrops in part, and figures and circles showing the relative amounts of gas at most of the mines. The structure is shown by 50-foot contour lines which give the position of the coal beds with reference to sea level but without relation to the surface of the land. The three principal coal beds are represented in the separate areas each by contour lines of distinctive character. In general the structure is the same whichever bed is represented, but the altitude is greater or less according to the interval between the beds. No data were available for showing the configuration of No. 2 coal in the Carbondale-Marion region and eastward. The contours given are based on known positions of the coal beds in many mines and on bore-hole records, being extended hypothetically across unexplored districts. In the region between Herrin, Christopher, Duquoin, and Carbondale the contours are based on 200 records. In some cases identification of beds in the bore-hole records is not entirely certain, and this introduces a possible error at certain localities which can not be corrected from the data available at this time.

In general, the structure in Saline, Williamson, and Franklin Counties is a monocline with low dips to the northward at an average rate of 50 feet to the mile. In Jackson County the strike swings around to the north and from De Soto to Duquoin there is a broad belt in which the dips are to the east. Approaching Duquoin the dips become steeper, and near the center of range 1 W., T. 6 S., the beds rise 350 feet in less than three-fourths of a mile. An anticline of considerable prominence extends along a north-to-south course parallel to this zone of steep dip; it passes through the northeastern corner of Jackson County.

The monocline in Williamson, Franklin, and Saline Counties has many local irregularities in direction and degree of dip and its continuity is interrupted by several low but well-marked anticlines and shallow synclines. These are all shown in Plate VII. True faults or dislocations of the strata are rare, but several small breaks have been found in some of the mines and there is a fault of considerable magnitude northwest of Murphysboro near the boundary line between Jackson and Perry Counties. Near Eldorado and Harrisburg the measures are cut by dikes of igneous rock which have altered the adjoining coal to coke.

CHARACTER OF THE COALS.

The Herrin coal is a high-grade bituminous coal in great favor among fuels in the Middle States markets. The average of 17 analyses by S. W. Parr, of the Illinois State Geological Survey, is given by Shaw and Savage[a] as follows:

Averages of analyses of 17 coal samples from Herrin district.

Condition of sample.	Total moisture.	Fixed carbon.	Volatile matter.	Ash.	Sulphur.	Calorific value.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*B. t. u.*
As received	9.11	48.79	32.66	9.43	1.65	11,799
Moisture free		53.02	36.18	10.39	1.86	13,004
Moisture and ash free		59.39	40.60			14,507

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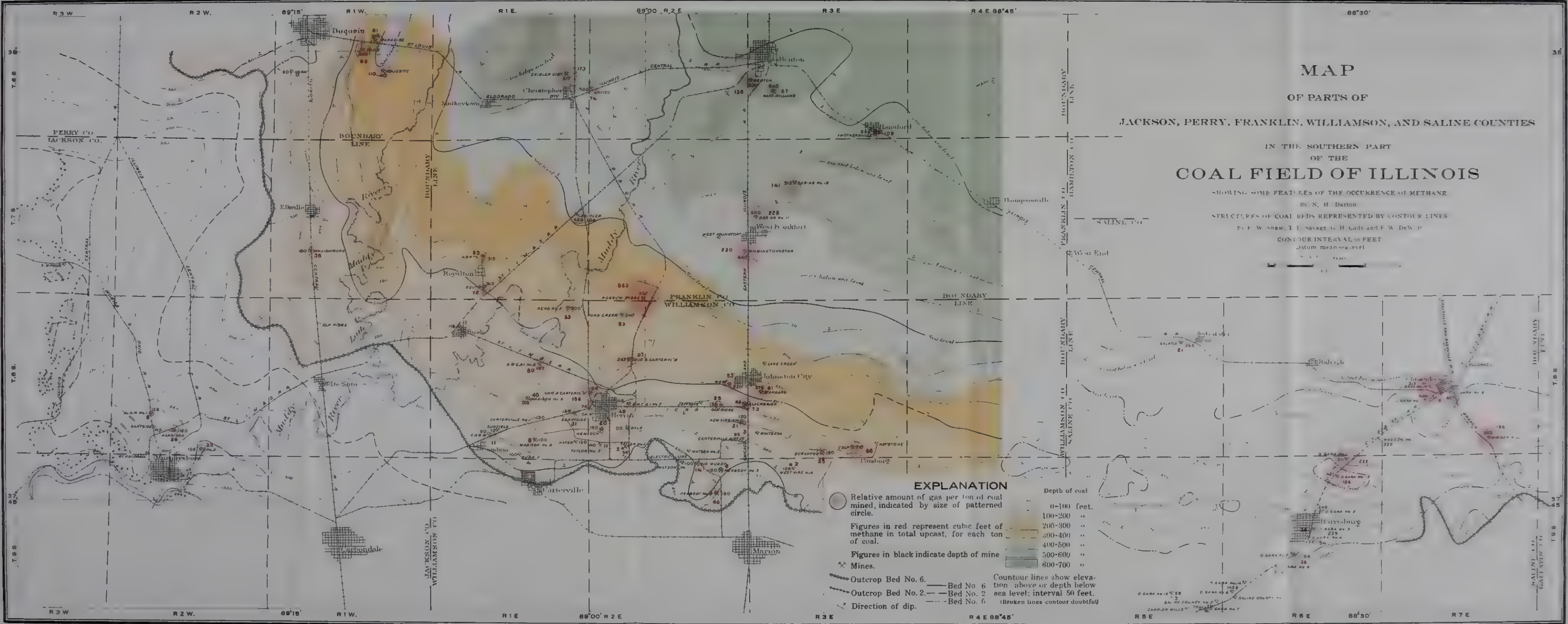
[a] Shaw, E. W., and Savage, T. E., Description of the Murphysboro and Herrin quadrangles: U. S. Geol. Survey Folio 185, 1912, p. 14.



MAP

OF PARTS OF

JACKSON, PERRY, FRANKLIN, WILLIAMSON, AND SALINE COUNTIES

IN THE SOUTHERN PART
OF THE
COAL FIELD OF ILLINOIS

SHOWING SOME FEATURES OF THE OCCURRENCE OF METHANE

By N. H. Darton

STRUCTURES OF COAL BEDS REPRESENTED BY CONTOUR LINES

By E. W. Shaw, T. E. Savage, G. H. Cady and F. W. DeWolf

CONTOUR INTERVAL 50 FEET
Datum mean sea level

EXPLANATION

○ Relative amount of gas per ton of coal mined, indicated by size of patterned circle.

Figures in red represent cubic feet of methane in total upcast, for each ton of coal.

Figures in black indicate depth of mine

⚒ Mines.

Outcrop Bed No. 6.

Outcrop Bed No. 2.

Direction of dip.

—— Bed No. 6
— — Bed No. 2
— · · — Bed No. 6

Depth of coal

0-100 feet.
100-200 "
200-300 "
300-400 "
400-500 "
500-600 "
600-700 "

Countour lines show elevation above or depth below sea level; interval 50 feet.
(Broken lines contour doubtful)

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The range of composition in these samples was as follows: Moisture, [illegible] to 11 per cent; ash, 6¾ to 12 per cent; and sulphur, 0.6 to 3½ per cent; and the heating value varied from 11,079 to 12,144 B. t. u.

An average sample from Galatia on the moisture-free basis contained 37.46 per cent volatile matter, 48.75 per cent fixed carbon, 13.79 per cent ash, and 3.73 per cent sulphur, and had a fuel value of 12,505 B. t. u.[a]

Calculated on the ash-free and moisture-free basis, the Murphysboro coal ranges from 53 to 63 per cent fixed carbon, 4 to 7 per cent ash, and 0.6 to 2 per cent sulphur. The average heating value of five samples is given at 14,749 B. t. u. (moisture and ash free), the calorific value of the separate samples ranging from 12,500 to 14,854 B. t. u. The coal ranks high as a fuel and much of it is called "Big Muddy coal."

The Harrisburg coal varies considerably in composition, but most of it is of high grade. The average of a series of samples from O'Gara mines Nos. 3, 8, 9, 12, and 14, No. 1 of the Wasson Coal Co., and No. 2 of the Saline County Coal Co. are given by De Wolf[b] as follows:

Average of analyses of seven samples[a] of coal No. 5 from Saline County, Ill.

[S. W. Parr, analyst.]

	Condition.						Referred to coal "moisture and ash free"		
	As received.			Moisture free.					
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
	P. ct.	*P. ct.*	*ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Moisture	6.64	4.43	5.90						
Volatile matter	36.20	33.48	34.69	38.52	35.66	36.88			
Fixed carbon	52.82	47.87	50.41	55.25	50.94	53.66			
Ash	10.89	7.17	8.98	11.58	7.62	9.55			
Sulphur	3.30	2.19	2.60	3.52	2.30	2.77			
B. t. u	12,883	12,159	12,552	13,700	12,942	13,197	14,962	14,830	14,910

[a] Samples include entire seam except in 1 mine where 1-inch pyrite ball was excluded.

OCCURRENCE OF GAS IN SOUTHERN ILLINOIS MINES.

In many of the Illinois mines the coal contains little explosive gas and it is given off so regularly and in such moderate volume that satisfactory ventilation is easily effected.[c] This is particularly the case near the outcrop zone where the cover is thin and much of the gas has drained off into the atmosphere. Many of the deeper mines in Franklin, Williamson, Perry, and Saline Counties, however, have considerable gas and in some instances it has exploded with serious results. The gas in this area occurs irregularly in the coal and the variations appear not to be closely related to depth of the coal bed or to structure of the strata. The amount of gas also varies considerably in different parts of the mines and at different stages of progress, being closely similar in these respects to gas occurrence in other coal-mining districts. There is a general relation between methane volume and depth up to 200 feet, with many local exceptions, however, when close comparison is attempted. In sampling the return air in the mines care was taken to select such returns as might be expected to show variations in the volume of gas that could be related to variations in conditions in the workings, but in many cases such relations could not be recognized. A sufficient number were obtained to illustrate very clearly the irregularity of occurrence of the gas even if they do not indicate the cause of the irregularity.

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[a] De Wolf, F. W., Coal investigations in Salem and Williamson Counties, Illinois: Illinois Geol. Survey Bull. 8, 1907, p. 245.

[b] De Wolf, F. W., op. cit., p. 228.

[c] See Parr, S. W., and Barker, Perry, The occluded gases in coal: University of Illinois, Bull. 32, 1909, 28 pp.

CONDITIONS IN REPRESENTATIVE MINES IN HERRIN BED.

MINES NEAR BENTON.

Two mines of considerable size have been worked for several years in the vicinity of Benton. They are both south of the city and reach the coal at depths slightly more than 600 feet. The beds lie nearly horizontal in broad undulations of the general monocline.

HART-WILLIAMS MINE.

The Hart-Williams mine, 2 miles south of Benton, reaches the coal at a depth of 640 feet, or about 175 feet below sea level. The bed is 10 feet thick. There is considerable methane throughout the workings, but the vigorous ventilation removes it. Occasional feeders are encountered, and gas enough to ignite escapes from all drill holes. The southeast workings are most gaseous, due perhaps to the fact that the beds there are traversed by many small rolls.

The returns of the mine were examined in 1912, on January 15 and 16, February 14, and in part on February 27. The air in the northeast return near the shaft was sampled January 15 and 16. It ventilated an area worked by 60 miners. The volume of air on the first test was 25,687 cubic feet per minute, and on the second test 23,120 feet. The percentage of methane was 0.07 on the first test and 0.06 on the second test, or about 16 cubic feet a minute, and the carbon dioxide content was 0.11 and 0.07 per cent in the two tests. The air of the northwest return had a volume near the shaft of 26,270 cubic feet and contained no methane and 0.04 per cent of carbon dioxide. The volume of air passing in the southwest return near the shaft was 31,930 cubic feet a minute. The air carried 0.08 per cent of methane, or 25½ cubic feet a minute, and 0.09 per cent of carbon dioxide. The southeast return from workings in which 95 miners were employed had a volume of 26,718 feet of air per minute, containing 0.18 per cent of methane, or 48 cubic feet a minute, and 0.15 per cent of carbon dioxide. The air in the entire east return—northeast and southeast—carried 64 cubic feet of methane a minute, and the air in the upcast from the mine carried 90 cubic feet of methane a minute.

On February 14 the sampling was repeated in part at other places, in order to subdivide the air in greater detail, with the following results:

Methane and carbon dioxide in return air in Hart-Williams mine, February 14, 1912.

Place where sample was taken.	Volume of air per minute.	Proportion of methane in return air.	Volume of methane per minute.	Proportion of carbon dioxide in mine air.
	Cu. ft.	*Per cent.*	*Cu. ft.*	*Per cent.*
First southeast entry, near shaft	21,120	0.20	42	0.26
Main east return, near shaft	20,830	.11	23	.32
First southwest entry, near shaft	15,912	.13	21	.15
East return, off third northwest airway	20,016	.17	34	.24
First crosscut, off third northwest airway	14,490	.02	3	.05
Main west return at overcast	18,480	.19	35	.15
Total upcast at shaft	110,848	.12	133	.61

On February 27 a sample taken in the first southeast air course, 350 feet southeast of the shaft, where the volume was 12,600 cubic feet a minute, contained 0.22 per cent methane and 0.17 per cent carbon dioxide.

BENTON MINE.

The Benton mine, on the southwestern margin of Benton, is 630 feet deep at the shaft, and the workings extend across the arch of a low anticline with axis trending nearly east and west. The mine gives off considerable gas, there being more in the western chambers than in the eastern ones.

The principal returns were sampled January 16 and March 9, 1912, while the mine was in full operation, and again in April 15, 1912, 16 days after mining had ceased. The samples were taken from the main north return near the shaft, which included all the north returns from a district in which 90 miners were working, from the main south return near the shaft and from the west return near the shaft, the two being the total return from the south workings. There were 80 miners employed in the area ventilated by the west return and 70 miners in the area ventilated by the main south return.

The results of the analysis of the three samples and their total by addition are as follows:

Methane and carbon dioxide in return air from Benton mine, January, March, and April, 1912.

Return.	Jan. 16, 1912.				Mar. 9, 1912.				Apr. 15, 1912.			
	Volume of air per minute.	Proportion of methane in return air.	Proportion of carbon dioxide in return air.	Volume of methane per minute.	Volume of air per minute.	Proportion of methane in return air.	Proportion of carbon dioxide in return air.	Volume of methane per minute.	Volume of air per minute.	Proportion of methane in return air.	Proportion of carbon dioxide in return air.	Volume of methane per minute.
	Cu. ft.	*P. ct.*	*P. ct.*	*Cu. ft.*	*Cu. ft.*	*P. ct.*	*P. ct.*	*Cu. ft.*	*Cu. ft.*	*P. ct.*	*P. ct.*	*Cu. ft.*
Total upcast at main shaft	101,200	......	......	......	92,290	0.21	0.66	194	57,144	......	......	......
Main north	47,400	0.20	0.10	95	[a] 38,016	.18	.11	68½	19,140	0.21	0.11	40
West	24,400	.18	.10	44	4,840	.34	.13	74	16,800	.49	.20	82
Main south	29,400	.18	.13	53	32,434	.16	.16	52	21,204	.20	.15	42

[a] Air not circulating in all of north workings owing to repairs; also some leak from overcast.

HANAFORD MINE.

The Hanaford mine at Smothersville is the deepest in the area investigated, as the coal lies 696 feet below the surface at the shaft, or nearly 200 feet below sea level. The mine produces 1,000 tons a day. About 6½ feet of the coal is mined. The return air was measured and sampled February 1, 1912, in the four principal returns.

The air in the first southwest return ventilated workings in which there were 12 miners. The return air, 325 feet west of the shaft, had a volume of 6,000 cubic feet per minute and contained 0.10 per cent of methane, or 6 cubic feet a minute, and 0.09 per cent of carbon dioxide. The main west return, in which a sample was taken at the second south airway, 400 feet west of the shaft, ventilated workings in which 16 miners were employed. It carried 8,520 cubic feet of air per minute, which contained 0.13 per cent methane, or 11 cubic feet a minute, and 0.05 per cent carbon dioxide. The air of the main east return, from workings in which there were 35 miners, had a volume 75 feet east of the shaft of 34,000 cubic feet per minute and contained 0.14 per cent methane, or 48 cubic feet a minute, and 0.05 per cent carbon dioxide. The first northwest return at the overcast 425 feet northwest of the shaft, from workings in which there were 10 miners, carried 7,540 cubic feet of air per minute, containing 0.14 per cent methane, or 10½ cubic feet a minute, and 0.09 per cent carbon dioxide. There was notable uniformity in the percentages of methane in the four returns and close conformity between the volume of methane and the amount of mining on each. However, the volume of methane from the southwest workings was a little less than from those on the northwest and main west returns.

MINES NEAR CHRISTOPHER.

Two mines near Christopher were selected as likely to illustrate the conditions in that part of the field—the mine of the United Mining Co., a mile east of the town, and the Zeigler District mine, a mile north of town.

UNITED MINE.

The United mine is 500 feet deep at the shaft and has a daily production of about 4,300 tons. The return from the north workings was sampled just north of the shaft, and with somewhat uncertain cross section, owing to obstruction of the air passage by cars; it indicated a current of 30,000 cubic feet per minute. This air contained 0.20 per cent of methane and 0.11 of carbon dioxide. The air of the south return, part of which was sampled in an airway just south of the shaft and part at an outlet in a crosscut at the shaft, had a total volume of 80,000 cubic feet a minute, the two samples containing 0.20 and 0.21 per cent of methane and 0.07 and 0.08 of carbon dioxide, respectively. The total volume of methane in the north return was 60 cubic feet a minute and in the south return and crosscut 160 cubic feet, or 220 in all. A part of this mine had a squeeze a few years ago and some of the workings were stopped off. It is known that a large amount of gas has accumulated in the inclosed workings. Samples of this air taken by S. O. Andros, of the department of mining engineering of the University of Illinois, from a 3-inch pipe through a stopping were found to contain 19.75 and 38.17 per cent methane and 0.03 and 0.20 per cent carbon dioxide, respectively.

Andros also obtained some samples of gas from a ¼-inch pipe which was inserted 6 inches into the rib at the sixth northeast entry near the fifth panel. The results of analysis of the two samples were as follows:

Composition of gas from pipe in rib coal in United mine.

Constituent.	Sample 1.	Sample 2.
	Per cent.	*Per cent.*
Methane	24.61	36.74
Carbon dioxide	.10	.10
Oxygen	14.54	11.89
Nitrogen	60.75	51.27

Samples of the average air taken by Andros in the sixth northeast cross entry contained 1.08 and 0.59 per cent methane and 0.06 and 0.05 per cent carbon dioxide, respectively. This entry, which has 23 working places on it, was reported to be the most gaseous cross entry in the mine.

ZEIGLER DISTRICT MINE.

The Zeigler District mine, a mile north of Christopher, is 517 feet deep at the shaft and has a production of about 2,000 tons a day.

Considerable gas was reported all through the mine, especially in chambers up the slope, where it has to be cleared out by close bratticing. The coal is 9 feet thick, of which 7 feet 4 inches is taken out. The main south return, in which a sample was taken just south of the main shaft, carried 64,320 cubic feet of air per minute, of which about one-half was from the southeast and one-half from the southwest workings. Part of the return air from the southeast workings escaped by a crosscut into the east side of the shaft, which adds 17,250 feet to the total volume, or 81,570 in all. The proportion of methane in the larger current was 0.19 per cent and in the smaller one 0.16 per cent, and of carbon dioxide 0.09 and 0.10 per cent. The main north return from the northeast and northwest workings, in which samples were taken near the shaft, carried 48,000 cubic feet of air per minute, which contained 0.19 per cent methane and 0.09 per cent carbon dioxide, practically the same proportions as in the south return. The total volumes, however, indicated by the tests were 150 cubic feet of methane a minute in the south return and 91 cubic feet in the north returns, closely comparable with amounts in the United mine.

ZEIGLER MINE.

Owing to explosions and fires several years ago the mine at Zeigler has the reputation of being a gaseous one. It is remote from other mines, the nearest ones being Rend No. 2 and the North mine at Royalton. The coal lies 418 feet below the surface at the shaft and dips at low angles to the north and northeast. The ordinary output of the mine is 2,300 tons a day and 8 or 9 feet of coal are taken out. The workings have an area of about 500 acres and part of them are walled off on account of roof falls caused by the explosions and fires.

The return-air samples were collected on February 2 and March 23 while the mine was under full operation and again on April 7, eight days after mining had ceased. The return air comes to the upcast in two main currents, one from the north side of the mine where there were 75 miners, and the other from the south side where a force of 150 miners was employed under ordinary conditions.

On February 2 the air in the north return near the shaft had a volume of 77,616 cubic feet a minute and contained 0.12 per cent methane and 0.08 per cent carbon dioxide; and in the south return, 84,800 feet, 0.07 per cent methane, and 0.10 per cent carbon dioxide.

On March 23 the north return had a volume of 64,288 cubic feet of air containing 0.24 per cent methane and 0.10 per cent carbon dioxide; the south return, with a volume of 90,396 feet, contained only 0.03 per cent methane and 0.05 per cent carbon dioxide.

Two weeks later, eight days after the mining had ceased and the fan was running less rapidly, the north return was passing 61,992 cubic feet of air, which contained 0.09 per cent methane and 0.05 per cent carbon dioxide. The south return, 700 feet south of the main shaft, was found to carry 57,600 cubic feet of air which contained 0.09 per cent methane, and 0.07 per cent carbon dioxide. Between this point and the shaft there was a leakage of about 15,000 cubic feet of air per minute from a fresh air overcast and a sample taken near the shaft at this time contained 0.03 per cent methane and 0.05 per cent carbon dioxide. This same leakage diluted the south returns in the two previous tests so that the 0.07 per cent of methane and 0.03 per cent of methane are slightly too low to represent the true character of the air. However, if calculation of the number of cubic feet of methane a minute be made from all the figures obtained near the shaft the following results will be obtained:

Volume of methane in returns in Zeigler mine, February to April, 1912.

Return.	Volume per minute.		
	Feb. 2.	Mar. 23.	Apr. 7.
	Cu. ft.	*Cu. ft.*	*Cu. ft.*
South	60	27	22
North	93	154	56

In all of the samples of south-side air, it was diluted with about 20 per cent of fresh air. The greatly increased amount of methane in the north return on March 23 could not be accounted for. There was a markedly less amount at all times on the north side, doubtless due to the fact that the number of miners employed on that side was only half as many as on the south side. The only structural difference is that the measures dip to the north and therefore the workings on the north side are slightly deeper than those on the south side.

MINES NEAR DUQUOIN.

The mines east and south of Duquoin produce coal from the Herrin bed. There is an abrupt rise in the strata a short distance east of the city in which the beds ascend nearly 350 feet. At the Majestic mine, 3 miles southeast of Duquoin, the coal is at sea level, or 412 feet below the surface, whereas in the Horn mine, 2 miles southwest of Duquoin, the depth is only 80 feet. In the belief that these diverse conditions of depth would show notable variations in gas in the coal, samples of return air were obtained from the Majestic, Paradise, Davis, and Horn mines. In the Paradise mine the air was sampled again two months later, 16 days after the mine had shut down.

PARADISE MINE.

The Paradise mine is on the railroad 3 miles east of Duquoin. The depth at the shaft was 380 feet and the production was about 1,800 tons a day with a force of 275 to 280 miners. The workings were mainly to the north of the shaft. The strata dip east with an inclination of 1½°. One thousand four hundred and fifty feet west of the shaft is a fault in which the beds on the west side drop 6 feet. The faulted block, which is about 700 feet wide, extends west to another fault with a displacement of 30 feet also on the west side. This latter block is flexed a short distance west of the fault by a sharp upturn on which the beds rise rapidly to the west. A short distance northwest of the shaft there is a marked basin, and then a rapid rise in which considerable gas was found. The coal bed is 10 feet thick, but in the first mining 7½ feet is taken out. The largest amount of gas was noted in the newest workings that were being vigorously advanced, especially in one area one-fourth of a mile southeast of the shaft.

The return air in this mine was sampled on February 15 on the main haulage road and runaround just north of the shaft. The volume was 67,450 cubic feet a minute, and it contained 0.15 per cent methane, or 101 cubic feet a minute, and 0.16 per cent of carbon dioxide. On April 15, after the mine had been shut down for 16 days, the air was sampled at the same locality; it had a volume of 15,770 cubic feet a minute and contained 0.26 per cent methane, 0.91 per cent carbon dioxide, and 19.15 per cent oxygen. This is equivalent to 41 cubic feet of methane, or less than half the volume at the time the previous sample was taken.

A special sample was taken on the first entry extending southeast of the north main east return 465 feet east of the shaft. Six miners had been working in this entry, which extended down the slope of the beds just one-fourth of a mile, with two small chambers at its lower end. At the time of the sampling the mine had not been worked for two days. The air in this return had a volume of 5,530 cubic feet a minute and contained 0.16 per cent methane and 0.11 per cent carbon dioxide. On April 15, 16 days after mining had ceased, the velocity of the ventilation seemed to be considerably diminished, as only about 1,000 feet of air was passing. This air was found to contain 0.33 per cent methane and 0.19 per cent carbon dioxide. It was reported that in this mine on March 15 a blower had been opened in room 5 off the fifth south gangway off No. 1 east entry.

Some face samples taken by S. O. Andros, of the department of mining engineering of the University of Illinois, in rooms on the fifth southeast A entry, contained considerable methane. One from room 5 contained 5.53 per cent and one from room 2, 10.35 per cent, showing that considerable gas was being given off in some of the working faces.

MAJESTIC MINE.

The Majestic mine is in the bottom of the basin 3 miles southeast of Duquoin and at the shaft the coal is about 420 feet below the surface. The ordinary production was 2,150 tons a day and about 300 miners were employed. The return air was sampled on February 15, after the mine had been idle two days. The main east return, which was sampled 100 feet east of the shaft, had a volume of 58,650 cubic feet a minute, and contained 0.14 per cent methane, or 82 cubic feet a minute, and 0.18 per cent carbon dioxide. The air in the main west return just west of the shaft had a volume of 68,530 feet and contained 0.12 per cent methane, or 83 cubic feet a minute, and 0.14 per cent carbon dioxide. The air in each of these returns ventilated workings about equal in extent and in each the number of miners employed was about the same. The uniformity in volume of methane shows that the conditions under which the gas was given off must have been uniform throughout the workings.

DAVIS MINE.

The Davis mine is one-half mile southwest of the Paradise mine and upon a slope of the monocline on which the strata rise rapidly toward Duquoin. The depth at the shaft is 320 feet and the production is 1,400 tons a day. Gas is noticed at places but no large amounts have been encountered. The mine was inspected on February 15, after mining had been suspended for two days. The workings are north of the shaft; the air is about equally divided in two currents between the west-side and the east-side workings. The main east return was found to carry 44,550 cubic feet of air a minute, containing 0.16 per cent methane, or 71 cubic feet a minute, and 0.27 per cent carbon dioxide. The west return carried 31,080 feet, containing 0.08 per cent methane, or 25 cubic feet a minute, and 0.10 per cent of carbon dioxide. The fact that nearly three times as great a volume of methane was carried in the east return as in the west return could not be accounted for. Doubtless the coal is more gaseous in the east side than in the west.

HORN MINE.

The Horn mine is 2 miles southwest of Duquoin. The coal is 7½ feet thick and at the shaft is about 80 feet below the surface. The return air was sampled on February 15 and found to carry no methane. The return air from the south half of the mine had a volume of about 7,200 cubic feet a minute and contained 0.19 per cent carbon dioxide;

the air in the north return had a volume of 14,800 feet and contained 0.36 per cent carbon dioxide. These results probably indicate that all of the methane had escaped, but considerable carbon dioxide was being produced by oxidation. At the time of sampling the mine was not being worked extensively.

MINES NEAR WEST FRANKFORT.

In several of the mines in the vicinity of West Frankfort the operators have had considerable difficulty with gas, and the belief is current that this district is the most gaseous one in the southern Illinois field. There have been explosions in the Dering No. 18 mine, one of which resulted in a serious fire, and at various times men have been injured to a greater or less extent by igniting gas. The mines are relatively deep, ranging from 440 feet at the Wilmington-Star to 512 feet at the Dering No. 18. The measures dip at a very low angle to the north or slightly northeast, the average slope being nearly 25 feet to the mile. There are no notable disturbances of the strata in the area, except occasional low rolls. The coal is the Herrin bed, which is about 8 feet thick at the Wilmington-Star mine and about 10 feet at the Dering No. 18.

DERING NO. 11 MINE.

The Dering No. 11 mine, which is about a mile north of West Frankfort, has a production of about 1,500 tons a day. The return air was sampled at several points in the mine, and also in the total upcast in the hoisting shaft on January 19, when the mine was in full operation, and again on April 4 after it had been shut down four and one-half days. The principal results are given in the table on page 189. The volume of the total return air, 92,820 cubic feet per minute, was obtained by the addition of the volumes of the separate splits in the mine. The analyses indicate that the total emanation of methane on January 19 was 204 cubic feet a minute. The sample from the third north return, in which a sample was taken 500 feet northeast of the shaft, represented air from the third and fourth northeast sections of the mine which were not being worked at the time of sampling but had been in operation the day before. The return air from the seventh and eighth north main entries and east fifth, sixth, seventh, and eighth southeast entries was taken 600 feet northeast of the shaft. This return carried about two-thirds of the air from the east side, and together with the third north return carried the entire ventilation from the east side of the mine, where about 125 miners were working ordinarily. This return carried 82 cubic feet of methane a minute. The air in the first northwest return was sampled 400 feet northwest of the shaft; it carried 33 cubic feet of methane a minute. It drained workings in which there had been a squeeze some time previously. The workings had since been opened, although not yet mined. The air of the main west return was found to carry 83 cubic feet of methane a minute or practically the same as in the main east. This air ventilated all the southwest and western part of the mine where 45 miners were employed in workings which were less than half as extensive as those on the east side. Another series of samples was taken on March 28 at the same places, and the sampling was repeated on April 4 after the mine had been shut down for four and one-half days. The results of the three series are given in the following:

Methane and carbon dioxide in return air of Dering No. 11 mine, Jan. 19, Mar. 28, and Apr. 4, 1912.

Return.	Jan. 19.				Mar. 28.				Apr. 4.			
	Volume of air per minute.	Methane content.	Carbon dioxide content.	Volume of methane per minute.	Volume of air per minute.	Methane content.	Carbon dioxide content.	Volume of methane per minute.	Volume of air per minute.	Methane content.	Carbon dioxide content.	Volume of methane per minute.
	Cu. ft.	*P. ct.*	*P. ct.*	*Cu. ft.*	*Cu. ft.*	*P. ct.*	*P. ct.*	*Cu. ft.*	*Cu. ft.*	*P. ct.*	*P. ct.*	*Cu. ft.*
Total upcast in main shaft...	92,820	0.22	0.11	204	84,625	0.32	0.13	271	71,068	0.25	0.10	177
Main west......	25,200	.29	.12	83	18,914	.48	.11	91	15,850	.36	.07	57
First northwest [a]........	22,050	.15	.12	33	21,295	.15	.13	32	19,656	.14	.23	27½
Main east [b].....	37,290	.22	.06	82	35,420	.19	.13	67	28,182	.24	.06	68
Third northeast [b]........	8,280	.25	.20	21	9,288	.26	.12	24	7,380	.28	.21	20½

[a] Workings not being mined.

[b] Total east return in these two returns.

The volume of methane in the total return and in the different returns was remarkably constant in January and March, but a general diminution was shown on April 4, four days after mining had ceased. Duplicate samples of the upcast taken by S. O. Andros in the hoisting shaft on January 9, 1912, were found to contain 0.27 and 0.29 per cent methane and 0.06 and 0.03 per cent carbon dioxide, respectively. The total volume of return air was estimated by Andros at 120,000 feet, but as it was much less than this at the time of the author's visits it probably may be taken at 90,000. This gives about 250 cubic feet as the total volume of methane per minute, a figure close to the average of the volumes found under similar conditions on January 19 and March 28 of the same year. Two entry samples were taken in duplicate by Andros at the same time; one taken at the face of the sixth stub entry off the fourth southeast entry contained 0.19 and 0.48 per cent methane, and another collected in the fifth stub off the same entry contained 0.16 and 0.05 per cent methane. The air in the latter return came from the third, fourth, fifth, and sixth panels and ventilated 30 rooms. The volume was not determined; the carbon dioxide content ranged from 0.02 to 0.06 per cent.

DERING NO. 18 MINE.

Dering No. 18 mine, situated 3 miles northeast of Dering No. 11 mine is in somewhat deeper-lying coal as the beds dip in that direction, but otherwise the conditions are similar to those in No. 11. The coal is 512 feet below the surface at the shaft and the bed is about 10 feet thick. The output is about 500 tons a day. Considerable amounts of gas were apparent at intervals in the mine, especially on the north side, where it could be ignited in some of the upgrade workings. The air in the returns was measured and sampled January 19, when the mine was working most of the time, and again on April 4, after it had been shut down four and one-half days. The principal results are given in the following table:

Methane and carbon dioxide in return air of Dering No. 18 mine, Jan. 19 and Apr. 4, 1912.

Place where sample was taken.	Jan. 19.				Apr. 4.			
	Volume of air per minute.	Methane content.	Carbon dioxide content.	Volume of methane per minute.	Volume of air per minute.	Methane content.	Carbon dioxide content.	Volume of methane per minute.
	Cu. ft.	*P. ct.*	*P. ct.*	*Cu. ft.*	*Cu. ft.*	*P. ct.*	*P. ct.*	*Cu. ft.*
Main south return, 350 feet southeast of shaft	18,240	0.06	0.05	11	13,500	0.11	0.05	15
West return off south side	9,180	.21	.06	19	4,000	.25	.08	10
Main north return	24,000	.08	.05	19	20,790	.06	.04	12½
Total	51,420	....	....	49	38,290	....	....	37½

There were working places for about 60 miners on the south side and the same number on the north side, but no mining was being done on the north side on January 19 or on the west return off the south side. The larger amount of methane from the south workings indicates a greater emanation, and owing to this variation the total amount on the south side (30 cubic feet) was considerably greater than the volume from the north side. Except in the main south return, there was a marked diminution in methane on April 4; but at this time a small part of the air from both returns, 6,000 cubic feet in all, made a short circuit to the upcast. Possibly the volume of methane in this leak was 4 cubic feet a minute.

WILMINGTON-STAR MINE.

The Wilmington-Star mine, which is one-fourth of a mile south of West Frankfort, is a new mine actively worked. The coal is 440 feet below the surface at the shaft and the bed is 8 feet thick. The mine is somewhat gaseous, but not more so in one part than in another, and occasional feeders are found. All the drill holes in the coal are gaseous and in most of them the gas can be lighted. The ventilation comes to the upcast in two returns, one from the south half and the other from the north half of the mine. The air in these returns was sampled on January 19 and March 28 while the mine was in active operation, producing about 1,500 tons a day, and again on April 11, when mining had been suspended 12 days. The results are given in the following table:

Methane and carbon dioxide in return air of Wilmington-Star mine, January to April, 1912.

Return.	Jan. 19.				Mar. 28.				Apr. 11.			
	Volume of air per minute.	Methane content.	Carbon dioxide content.	Volume of methane per minute.	Volume of air per minute.	Methane content.	Carbon dioxide content.	Volume of methane per minute.	Volume of air per minute.	Methane content.	Carbon dioxide content.	Volume of methane per minute.
	Cu. ft.	*P. ct.*	*P. ct.*	*Cu. ft.*	*Cu. ft.*	*P. ct.*	*P. ct.*	*Cu. ft.*	*Cu. ft.*	*P. ct.*	*P. ct.*	*Cu. ft.*
Main north	61,800	0.14	0.05	86½	70,070	0.17	0.06	119	22,400	0.31	0.06	69
Main south	61,067	.14	.09	85½	58,240	.16	.72	93	25,410	.24	.04	61

The air of the main north return, which was from all workings north of the shaft, was sampled 300 yards north of the shaft. Sixty-two miners were employed in the north workings. The sample of south-return air was taken 800 feet southwest of the shaft. On March 28 the methane had increased since the previous test to 93 cubic feet in the main north return and 119 cubic feet in the main south return, and there was a notable increase in carbon dioxide on the south side. On April 11, after 12 days of no mining, the air volume was diminished to less than half. The volume of methane was 61 cubic feet a minute from the south side and 69 cubic feet from the north side, a marked diminution which can be clearly connected with the cessation of mining.

MINES ABOUT JOHNSTON CITY.

The coal of the Herrin bed is mined extensively about Johnston City. The depth of the coal bed below the surface in these mines varies from 96 to 276 feet, increasing gradually from south to north.

STANDARD OR EAST MINE.

The deepest mine is the Standard or East mine a mile southeast of Johnston City, where the coal at the shaft lies 276 feet below the surface. The thickness of the coal worked is about 7 feet. The air was measured and sampled on February 7, when the mine was in full operation, and again on April 11, 12 days after mining had ceased. Considerable methane appeared in places, especially in the region drained by the main west return, and at times small explosions have occurred. The air in the east return, which was sampled 450 feet southeast of the shaft, ventilated workings in which 65 miners were employed. Its volume was 14,100 cubic feet and it contained 0.26 per cent methane, or nearly 37 cubic feet a minute, and 10 per cent carbon dioxide.

The air from the western half of the mine, in which 65 miners were employed, was sampled in the first northwest return 450 feet southwest of the shaft; it had a volume of 15,620 cubic feet a minute and contained 0.12 per cent methane, or 19 cubic feet a minute, and 0.09 per cent carbon dioxide. A small split of the main west-return air in the main west gangway, 250 feet south and 1,350 feet west of the shaft, was also sampled. It had a low velocity and contained 0.43 per cent methane and 0.32 per cent carbon dioxide.

On April 11, after 12 days of no mining, the east return 200 feet east of the shaft was found to have a volume of 10,950 cubic feet of air a minute, containing 0.29 per cent methane, or 32 cubic feet a minute, and 0.06 per cent carbon dioxide. The volume of the west return was 11,970 feet, containing 0.25 per cent methane, or 30 cubic feet a minute, and 0.07 per cent of carbon dioxide. At the first visit the upcast was to the fan, while on the later one the upcast was at the hoisting shaft, and the fan was moving at about half speed, but otherwise the air courses were unchanged. For some time past the main west entry had been very gaseous, so that it had to be bratticed up to the face. However, the amount of methane on that side was practically the same on April 11 as on February 7.

WEST MINE.

At the West mine, on the western edge of Johnston City, the coal is 220 feet below the surface at the shaft. The bed is 8½ to 9 feet thick. The mine was new but produced about 2,800 tons of coal a day. Its ventilation was divided into an eastern half and a western half, there being about 200 miners on each side. On February 7 the main east return 150 feet from the shaft was found to carry 33,920 cubic feet of air per minute, which contained 0.28 per cent methane, or 95 cubic feet a minute, and 0.25 per cent carbon dioxide. The main west return 150 feet northwest of the shaft carried 24,500 cubic feet of air, which contained 0.04 per cent methane, or 10 cubic feet a minute, and 0.07 per cent of carbon dioxide. Uniform amounts of methane were reported to be given off in the working faces in the mine and many holes could be lighted, but no blowers had been observed. The much greater volume of methane in the east return as compared with that in the west return, nearly 10 to 1, has no apparent explanation.

BLACKBRIER MINE.

The Blackbrier mine, a mile south of Johnston City is 185 feet deep at the shaft and produces 1,100 tons a day; 156 miners are employed. The active workings in this mine are all east of the shaft. The return air from them was sampled on March 12, and again on April 11, 12 days after mining had ceased. On March 12 the return air 150 feet east of the shaft had a volume of 23,120 cubic feet and contained 0.24 per cent methane, or 55½ cubic feet a minute, and 0.46 per cent carbon dioxide. The air in the same return taken at the 11th south entry a quarter of a mile farther in, had a volume of 9,240 cubic feet a minute and contained 0.30 per cent methane and 0.30 per cent carbon dioxide. One hundred and twenty miners were employed in these workings. These same currents were tested on April 11. At the place 150 feet east of the shaft, the return had a volume of 22,000 cubic feet of air containing 0.14 per cent methane, or 31 cubic feet a minute, and 0.28 per cent carbon dioxide. The volume of methane given off in this mine after mining had ceased diminished from 55½ to 31 cubic feet, a marked decrease.

When the shaft was sunk in 1894 a great gas blower was opened in driving the main entry, 20 feet west of the shaft. The gas was drained off in a 4-inch pipe and burned; it sustained a large flame for two years. When the entry reached a point 150 feet east and 800 feet south of the shaft, another blower was opened, causing an explosion that killed five men. Soon after this blower began the one near the shaft bottom ceased. Finally the second one also died out. The old workings west of the shaft were never very gaseous, most of the gas occurring in working faces to the extreme northeast.

NEW VIRGINIA MINE.

The New Virginia mine is 1½ miles south of Johnston City and nearly a mile south of the Blackbrier mine. It produced 1,100 tons a day and about 125 miners were employed. The coal is about 6½ feet thick and lies 120 feet below the surface at the shaft. Very little gas has been observed in the mine and it was mostly in the northwest workings. The air in the mine was sampled on March 12. The main return carrying all of the south and part of the west ventilation, from workings in which 22 miners were employed, was tested 150 feet southwest of the shaft. This return air was found to have a volume of 10,170 cubic feet a minute and it contained 0.06 per cent of methane, or 6 cubic feet a minute, and 0.23 per cent of carbon dioxide. The north return carried air from part of the west workings and a large area of old east workings where 38 to 40 miners were working. The return air, which was sampled 150 feet northwest of the shaft where the volume was 10,908 cubic feet a minute, contained 0.06 per cent methane, or 6½ cubic feet a minute, and 0.33 per cent carbon dioxide. The southeast return carried the balance of the air from the east and south workings, in which 60 miners were employed. This return was near the upcast 100 feet north of the shaft where the volume of the passing air was found to be 15,120 cubic feet of air a minute. The air contained 0.02 per cent methane, or 3 cubic feet a minute, and a large proportion of carbon dioxide, 1.43 per cent.

CARTERVILLE DISTRICT MINE.

The Carterville District mine, a half mile south of the New Virginia mine, is a somewhat larger producer than the others, the production being 1,450 tons. It is only 96 feet deep at the shaft. At the time of the author's visit on March 12, the fan was running at about half speed. The air of the main west return which ventilated the west half of the mine, in which 77 miners were employed, was sampled 370 feet west of the shaft. The volume of air was 7,250 feet and it contained 0.16 per cent carbon dioxide and no methane. In the main east return, from workings in which about 48 miners were employed, 350 feet east of the shaft the volume of air was 10,530 cubic feet and it contained 0.02 per cent methane, or 3 cubic feet a minute, and 0.30 per cent carbon dioxide.

OAK RIDGE MINE.

At the Oak Ridge mine, 1½ miles west of Johnston City, the conditions were closely similar to those in the Blackbrier mine a mile east. The depth is 135 feet at the shaft, the daily production was 1,000 to 1,200 tons, and 145 miners were employed. The coal, which is about 9 feet thick, gave off considerable gas in places, mostly on the north side, where the gas could be lighted in drill holes and crevices in the faces. There is a 40-foot fault with a drop on the west side along the west margin of the workings and a smaller fault northeast of the shaft, but these were not gaseous. The greater part of the return air from this mine was measured and sampled at a point 240 feet west of the shaft. This air also ventilated a large area of old workings. Its volume on March 25 was 20,880 cubic feet a minute and it contained 0.08 per cent of methane, or 16 cubic feet a minute, and 0.18 per cent of carbon dioxide. The east-return air 100 feet east of the shaft had a volume of 25,500 cubic feet, and it contained 0.01 per cent methane, or 2½ cubic feet a minute, and 0.07 per cent carbon dioxide. The total volume of methane was 25 cubic feet a minute or just about the same as in the Colp mine, which was visited later.

MINES NORTHEAST OF MARION.

There are several mines in the Herrin coal bed between Marion and Pittsburgh. In this region the coal measures dip to the northeast at low angles and there are no special disturbances of the strata.

COLP MINE.

The Colp mine, which is a mile northwest of Pittsburgh, is a small, new mine with a daily output of about 400 tons. Thirty-six miners were employed at the time of the author's visit. The coal bed is 5½ to 6 feet thick and lies 210 feet below the surface. The total return air, which was sampled on March 26 near the shaft, had a volume of 40,600 cubic feet, and it contained 0.06 per cent methane, or 24 cubic feet per minute, and 0.07 per cent carbon dioxide.

SCRANTON MINE.

The Scranton mine, a mile southwest of the Colp mine, was 160 feet deep at the shaft. At the time of the author's visit 90 miners were employed, and the production was about 650 tons of coal a day. The total return air, sampled March 26 at two places near the shaft, had a volume of 31,500 cubic feet a minute, and it contained 0.08 per cent methane and 0.08 per cent carbon dioxide.

WEST VIRGINIA MINE.

The West Virginia mine, which is a mile southwest of the Scranton mine, or 2½ miles northeast of Marion, is somewhat larger than the other two, its output being 1,200 tons a day. The depth at the shaft is 108 feet and the coal is 6 to 7½ feet thick. Some gas was observed in places in this mine, especially a small feeder, and in many of the drill holes it could be lighted. The return air was sampled on March 26. The main north return near the shaft carried 26,112 feet of air, containing 0.01 per cent of methane, or 2½ cubic feet a minute, and 0.08 per cent of carbon dioxide. There was a small admixture of air from the south part of the mine in this return in a runaround near the shaft. Fifteen miners were employed in the workings ventilated by this air current. The air in the south return, which ventilated about two-thirds of the mine and supplied 100 miners, was sampled at the shaft. Its volume was 36,260 cubic feet, and it contained 0.09 per cent carbon dioxide and no methane.

MINES NORTHWEST OF MARION.

There is a group of mines 3 miles northwest of Marion in which the conditions present some interesting features. Three were examined, the Peabody No. 2 and No. 3 and the Big Muddy.

PEABODY NO. 3 MINE.

At the Peabody No. 3 mine the coal is 100 feet below the surface at the shaft and although the bed is 9 feet thick only 7½ feet is taken out. It is covered by a thick body of shale and the strata dip northwest at a low angle. The mine produces 2,400 tons a day. The ventilation is in two main airways, both draining about the same extent of workings, but there is some mingling of air currents in certain parts of the mine. The main southwest and southeast returns combined, of which a sample was taken about 300 feet south of the shaft, were found to carry 24,651 feet of air, which contained 0.03 per cent methane, or 7 cubic feet a minute, and 0.21 per cent of carbon dioxide. This return comes from workings in which 120 miners were employed. The main north-return airway was found to carry 12,320 feet of air, which contained 0.06 per cent of methane, or 7 cubic feet a minute, and 0.23 per cent carbon dioxide. About 80 men were mining coal in the workings ventilated by this air. The notable feature in these results is that equal volumes of methane were coming from the two halves of the mine, although the fresh workings in the deeper parts were somewhat less extensive than those on the south side. The small total volume is undoubtedly due to the shallowness of the mine and probably would be less were it not for the heavy body of shale overlying the coal.

PEABODY NO. 2 MINE.

A mile south of the Peabody No. 3 mine is the Peabody No. 2 mine, where the shaft reaches the Herrin coal at a depth of only 80 feet about a mile from the outcrop. This mine employed about 160 miners and produced 1,200 tons a day. The bed is 9 feet thick, but only 7½ feet was mined. The mine was about 500 acres in extent, most of the part lying east of the shaft being old workings. All the new workings were to the west. Some of the return air from this mine escaped to the south through outcrop workings. The upcast air at the shaft was found to contain 0.11 per cent methane and 0.11 per cent carbon dioxide. The volume was not determined but was stated to be about 50,000 cubic feet a minute, which would indicate 55 cubic feet of methane a minute, a volume greatly in excess of that from other shallow mines in the district. The main west and north returns in the new workings, where about 100 miners were employed, in which samples were taken 1,200 feet west of the shaft, carried 25,550 feet of air, which contained 0.05 per cent methane, or 13 cubic feet a minute, and 0.10 per cent carbon dioxide.

BIG MUDDY MINE.

The Big Muddy mine is a mile northwest of the Peabody No. 3 mine on the opposite slope of a low anticline. The strata dip westward. The shaft was 100 feet deep and the bed is 9 feet thick, of which 7 feet was taken out. The production was 1,500 tons a day.

No gas was ever observed by the miners in this mine. A fault with a throw of 51 feet extends from north to south across the east side of the mine and there are many rolls and minor faults.

The ventilating current in this mine came to the upcast in two main returns, one from the east half of the mine where 65 miners were working, and the other from the west section where 97 miners were working. The air was sampled on January 24, and again on April 13, two weeks after mining had been suspended.

In the first visit, the east return, at the head of the rock slope just east of the shaft, carried 28,620 cubic feet of air per minute which contained 0.04 per cent methane, or 11½ cubic feet a minute, and 0.10 per cent carbon dioxide. The west return, in the second south, sixth west entry, carried 5,700 feet of air which contained 0.05 per cent methane or 3 cubic feet a minute, and 0.14 per cent carbon dioxide. The small volume of the air was stated to be due to some break far out in the workings. The normal volume was about four times as much.

On April 13 the fan was running at greatly diminished speed, as mining was suspended. The east return, tested at the same place as before, was found to carry 14,668 feet of air which contained 0.02 per cent methane, equivalent to nearly 3 cubic feet per minute, and 0.19 per cent carbon dioxide. The air in the east return, one-half mile south of the shaft, had a slight velocity, and seemingly its volume was not over 1,000 feet a minute. It contained 0.02 per cent methane and 0.62 per cent carbon dioxide. These figures show a marked diminution in the amount of methane given off during the cessation of working and precisely the same volume of carbon dioxide in the east return and approximately the same in the west return.

MINES SOUTH AND WEST OF HERRIN.

Samples of return air were collected in the Hemlock, Taylor No. 1, and Taylor No. 2 mines south of Herrin. They were taken at two periods, one on March 8 when the mines were operating, and the others on April 10, 11 days after the mining had ceased.

The mines were relatively shallow, the Hemlock being 155 feet deep at the shaft, the Taylor No. 2, 140 feet, and the Taylor No. 1, 53 feet. The Hemlock mine is in the southern edge of the town; the Taylor No. 2 a half mile due south of the Hemlock mine; and the Taylor No. 1 about a mile due east of the Taylor No. 2. The mines were all small and relatively new with little old workings and no noteworthy structural features. The strata dip gently northward.

HEMLOCK MINE.

In both samplings of the Hemlock returns, the east and west return air currents were sampled separately. On March 8 the air in the main west return, at a point 250 feet west of the shaft, was found to have a volume of 30,512 cubic feet a minute, and contained 0.02 per cent methane and 0.10 per cent carbon dioxide. The air in the east return, sampled 100 feet east of the shaft, had a volume of 23,870 cubic feet a minute and contained 0.01 per cent methane and 0.05 per cent carbon dioxide. The mine was being worked by 45 miners and its average daily output was 700 tons. The bed is 9 feet thick and about 7½ feet of it was mined.

Little gas was reported in the mine but some methane was noticeable in the fresh headings in the downward pitch on the second north entry off the east gangway. The analyses indicate that the total outflow of methane from the Hemlock mine was only 9½ cubic feet a minute, of which 7 cubic feet was from the west workings and nearly 2½ cubic feet from the east workings.

On April 10, 11 days after the mine had ceased operating, the sampling was repeated. At this time the direction of the air current was reversed, the fan exhausting and running at much less speed. The air of the main east return, sampled near the foot of the fan shaft, had a volume of 19,180 cubic feet a minute and contained 0.04 per cent methane, or 8 cubic feet a minute, and 0.07 per cent carbon dioxide. The air of the main west return at the foot of the fan shaft had a volume of 17,892 feet, and contained about the same volume of methane as the east return, or a little less than 8 feet a minute, and 0.12 per cent of carbon dioxide. The volume of methane per minute in the west return was therefore slightly more than when the mine was in operation, whereas in the east return it was 2½ times as much as in the first test, an increase that is difficult to explain.

TAYLOR NO. 2 MINE.

The conditions at the Taylor No. 2 mine were closely similar to those at the Hemlock, but the former is about twice as large. On March 8 the main west return carried 31,875 feet of air, which contained only 0.02 per cent methane, and the main east return and its parallel entry, about 26,832 feet of air, contained the same percentage; the carbon dioxide content was 0.09 per cent. There were at the time 80 miners on the west side and 100 on the east side, the entire output being about 1,500 tons a day. The total volume of methane was nearly 5½ cubic feet a minute on the east side and nearly 6½ cubic feet on the west side. The east side workings extended much deeper than those in the west side. On April 10, after 11 days of no working, the air volume was about half and no trace of methane was found in either return. The percentage of carbon dioxide was slightly increased, but the volume per minute was considerably less. No gas has ever been noticed in this mine.

TAYLOR NO. 1 MINE.

The Taylor No. 1 mine was only 55 feet deep and no gas had ever been reported in it. The production was 1,000 tons a day. The workings were equally divided into two sides, east and west, with about 150 miners in each side. The east return carried 14,000 cubic feet a minute, which contained only 0.01 per cent methane and 0.07 per cent carbon dioxide. The volume of air in the west return was 18,000 cubic feet a minute and the air contained 0.10 per cent carbon dioxide and no methane. The total volume of methane from the mine, therefore, was only 1.4 cubic feet a minute, and this was all from the east side where the workings were shallower than on the other side.

SUNNYSIDE MINE.

The Sunnyside mine, which is a mile west of Herrin, presented conditions similar to those in the Hemlock mine, but it was considerably larger. The depth to the coal was 150 feet at the shaft, 7½ feet of coal was taken out, and the output was 2,000 tons a day, 200 miners being employed. The ventilation of the mine was by two main returns, the air of which was measured and sampled on January 31. The east return, 250 feet southwest of the shaft, carried 39,150 cubic feet of air, which contained 0.06 per cent methane, or 23½ cubic feet a minute, and 0.03 per cent carbon dioxide. This air ventilated all the east side of the mine. The west return, 300 feet southwest of the shaft, was found to carry 47,554 feet of air, which contained 0.04 per cent methane, or 19 cubic feet a minute, and 0.03 per cent carbon dioxide. The similarity of the figures show closely uniform emanation of methane on the two sides of this mine.

CHICAGO & CARTERVILLE CO. MINES.

The "A" mine of the Chicago & Carterville Co. is 1 mile northwest of Herrin and the "B" mine 2 miles northeast of that city. The "A" mine was 186 feet deep and the "B" mine 247 feet. Both are mines of large extent and with old workings of considerable area. The "A" mine had an output of about 2,100 tons a day and the "B" mine had an output of 1,500 tons a day. The coal is 7½ feet thick in the "B" mine and the strata dip gently with no especial local disturbances. The "B" mine is in a broad irregular syncline in the general northerly monocline with the dips northwest. Both of these mines were sampled while in full operation and again after operation had been suspended a while.

"A" MINE.

The main returns of the "A" mine came to the upcast in five principal courses, three of them from the north and two from the south. The proportions of methane and carbon dioxide on January 31 and April 10, 1912, were as follows:

Methane and carbon dioxide in return air from "A" mine, January and April, 1912.

Return.	Jan. 31.				Apr. 10.			
	Volume of air per minute.	Proportion of methane in return air.	Proportion of carbon dioxide in return air.	Volume of methane per minute.	Volume of air per minute.	Proportion of methane in return air.	Proportion of carbon dioxide in return air.	Volume of methane per minute.
	Cu. ft.	*Per ct.*	*Per ct.*	*Cu. ft.*	*Cu. ft.*	*Per ct.*	*Per ct.*	*Cu. ft.*
Main north, 500 feet northwest of shaft	33,120	0.25	....	83	14,000	0.15	0.12	21
Third west north, 500 feet north of shaft	15,576	.03	0.05	8	13,650	.10	.16	14
First east north	16,884	.20	1.21	33	32,680	.16	.14	52
Second west south	18,400	.19	1.36	35	13,860	.20	.61	27
Main south	31,668	....	....	....	20,800	.07	.11	14½

These figures show great difference in volume of methane given off in different parts of the mine, especially in the smaller amount in the third west north return, where there was a large coal production.

The sampling was repeated at the same places on April 10, 11 days after mining had ceased, but owing to a change in the airways some of the air of the returns which formerly came out at the main north return then came out by the first east north return after draining old workings. The total volume of methane in the north workings, however, was only 87 cubic feet a minute on April 10, as compared with 124 feet when the mine was in operation, and the west south return showed a slight diminution.

Disregarding the main south return the total volume of methane in the other returns was 159 cubic feet per minute on January 31 and 114 feet on April 10, a notable diminution. The increased amount in the first east north return was due mainly to the fact that the air volume was doubled and gas brought in from old workings on the main north return. The cause of the increase in the third west north return was not apparent.

In one part of the "A" mine an area of 325 by 500 feet had been walled off on account of defective ventilation. The air in this chamber contained a large volume of methane, and showed 0.35 inch of pressure on the water gage.

"B" MINE.

The "B" mine was visited on March 8 and April 12, 1912. The returns from this mine were in two courses, the main east ventilating workings operated by 75 miners, and the main west from workings in which 150 miners were employed. On March 8 the main east return air 300 feet southeast of the shaft had a volume of 31,350 cubic feet per minute and contained 0.15 per cent methane and 0.05 per cent carbon dioxide. The air in the main west return 300 feet southwest of the shaft had a volume of 54,225 feet and contained 0.10 per cent methane and 0.06 per cent carbon dioxide. The volume of methane a minute was 47 cubic feet in the east return and 54 in the west return, a rather slight difference when it is considered that twice as much coal was being mined on the west side. On April 12, after 13 days of no mining, the air in the returns was measured and sampled at the same places. The fan was making 25 per cent fewer revolutions per minute. The main east return carried 26,250 feet of air containing 0.16 per cent methane and 0.11 per cent carbon dioxide, and the main west return carried 51,440 feet of air containing 0.19 per cent methane and 0.14 per cent carbon dioxide. The increase in the carbon dioxide is a notable feature. The total volume of the methane in the main east return had diminished slightly to 42 cubic feet a minute, whereas in the main west return it had increased to 98 feet, nearly double the volume on March 28.

POND CREEK, POSSUM RIDGE, AND REND NO. 2 MINES.

The Pond Creek mine, which is 3½ miles north of Herrin, the Possum Ridge mine, a mile farther northeast, and the Rend mine to the northwest represent a part of the Herrin coal field in which there are only a few mines. The beds are on the regular north and northeast slope of the general monocline and present no notable local disturbances except a small fault in the northeast part of the Possum Ridge workings.

POND CREEK MINE.

The Pond Creek mine produces about 1,000 tons a day. The coal worked is about 7½ feet thick and the depth at the shaft is 240 feet. There were two main-return air currents, which were sampled separately on March 18. The air of the main south return, which was sampled 300 feet southeast of the shaft, ventilated workings in which 57 miners were removing coal. The volume of air passing was 9,108 cubic feet per minute, and it contained 0.30 per cent methane, or 27 cubic feet per minute, and 0.11 per cent carbon dioxide. The air in the main west return, which was sampled 300 feet west of the shaft, ventilated workings in which 48 miners were employed. It carried 10,340 cubic feet of air, which contained 0.09 per cent methane, or 9 cubic feet a minute, and 0.15 per cent carbon dioxide. No reason is apparent for there being three times as much methane on the east side as on the west, in which the workings were only slightly more extensive. Gas shows occasionally in lamps in this mine, but its volume is seldom appreciable.

POSSUM RIDGE MINE.

The Possum Ridge mine is similar in production and extent of workings to the Pond Creek mine but the coal lies deeper, being 357 feet below surface at the shaft, and is 9½ to 10 feet thick. The returns are from east and west sides with about two-thirds of the workings on the west side.

On March 18, the main west return 350 feet southwest of the shaft was found to carry 31,724 cubic feet of air per minute, which contained 1.19 per cent methane and 0.20 per cent carbon dioxide. The volume of methane in this return was 377½ cubic feet a minute, which is the highest found in any of the mines visited in this district. The cause of the great volume of methane from the west workings was not apparent and its existence there was not known to the operators. Sixty-five miners were working on the west side.

The main east return 350 feet southeast of the shaft carried 20,237 feet of air which contained 0.07 per cent methane or 14 cubic feet a minute, and 0.08 per cent carbon dioxide. Thirty miners worked on the east side.

REND NO. 2 MINE.

The Rend No. 2 mine presented conditions closely similar to those in the other two mines. The depth at the shaft was 215 feet, 7½ to 8 feet of coal was removed, the output was 2,000 tons a day, and 175 miners were employed. There were two main returns, one from the west and one from the east workings, but there was much admixture of air back in the mine. On March 18, the main west return just west of the shaft carried 59,160 cubic feet of air per minute, which contained 0.05 per cent methane, or 29½ cubic feet a minute, and 0.06 per cent carbon dioxide; and the main east return, 20 feet east of the shaft, carried 47,600 feet of air containing 0.07 per cent methane or 33 cubic feet a minute, and 0.03 per cent carbon dioxide. An air current of about 14,000 feet comes to the shaft through a pump hole, about half from the east and half from the west. If it be assumed that this return carried an average of about 0.06 per cent methane or 8 cubic feet per minute the total methane in the returns was 71 cubic feet a minute. Gas was given off in large amounts in the south and east entries which are on an upgrade. Several small faults were somewhat gaseous, one of them especially so.

MINES NORTH OF CARTERVILLE.

There are large mines at frequent intervals north of Carterville following the Herrin coal down the north sloping monocline. In the first one, the Burr C, a mile out of town, the coal is at a depth of 100 feet, whereas the coal in the No. 8 mine of the Big Muddy Coal & Iron Co., which is 5 miles north, is 169 feet below the surface.

BURR C MINE.

At the Burr C mine, which had an output of 1,500 to 1,600 tons a day, the return was in two main currents, which were measured and sampled on March 5, 1912. The main east return 1,300 feet east of the shaft carried 11,200 cubic feet of air per minute, containing 0.06 per cent methane, or 6¾ cubic feet a minute, and 0.26 per cent carbon dioxide. This air ventilated the south half of the east side of the mine or about one-fourth of the area of active workings, in which 53 miners were employed. The return air from the main west and the north half of the east-side workings, which was sampled 1,000 feet east of the shaft, ventilated about three-fourths of the workings, in which 130 miners were employed. The volume was 47,500 cubic feet of air and it contained 0.01 per cent methane or 4¾ cubic feet a minute, and 0.11 per cent carbon dioxide. The smaller volume of methane in this return as compared with that from the area of smaller workings on the east side is a notable feature.

MADISON NO. 8 MINE.

The Madison No. 8 mine is a mile north of the Burr C mine. About 180 miners were employed, and the output averaged nearly 1,500 tons a day. The depth at the shaft was 100 feet. The air of the main return was sampled 10 feet west of the hoisting shaft and measured at several places in the vicinity. The total volume of upcast air was 96,517 cubic feet per minute, of which about 30,000 feet escaped through an old shaft. The return air at the shaft contained 0.01 per cent methane or 9½ cubic feet a minute, and 0.15 per cent of carbon dioxide.

MADISON NO. 9 MINE.

The Madison No. 9 mine is 2 miles north of the No. 8 mine and the shaft was 120 feet deep. The mine was larger than the others, having an output of 2,500 tons a day. Seven and one-half feet of coal was mined. The main returns were in two airways, one from the west half of the mine, in which 200 miners were employed, and the other from the east half, in which 150 miners were employed. The main west return air was sampled 250 feet west of the shaft and carried 58,743 cubic feet of air, which contained 0.06 per cent methane, or 35 cubic feet a minute, and 0.09 per cent carbon dioxide. The east return, at the overcast 350 feet east and south of the shaft, carried 48,858 feet of air, which contained 0.07 per cent methane, or 34 cubic feet a minute, and 0.12 per cent carbon dioxide. The uniformity in amounts of methane on the two sides of the mine and the much greater amount as compared to that in the other mines south are noteworthy features.

Some gas was given off in the east-side workings and on the west side there was a feeder that burned continuously with a blaze 2 feet high. No gas was reported in drill holes. Most of the notable gas is in narrow zones of soft, wet coal extending across the mine and it appears to issue from the bottom clay.

C. & B. M. MINE.

The C. & B. M. mine of the Carterville & Big Muddy Co. is a short distance northeast of Cambria, or 1½ miles northwest of the Burr C mine. The depth was 86 feet at the shaft and 7½ to 8 feet of coal was mined from a 10-foot bed. The output was 900 to 1,100 tons, which was mined by about 150 miners. The return air from all but a very small part of the workings was sampled just below the southwest entry 1,800 feet north of the shaft. The return air had a volume of 36,000 feet and it contained 0.02 per cent methane, or 7 cubic feet a minute, and 0.22 per cent carbon dioxide. The air not represented in the sample was a current of about 4,000 cubic feet, ventilating workings in which 6 miners were taking down coal. The air passed into the upcast farther up the slope. No gas has ever been noted in this mine.

MINES NO. 7 AND NO. 8 OF THE BIG MUDDY COAL & IRON CO.

The two large mines of the Big Muddy Coal & Iron Co., mine No. 7, 1 mile east of Herrin, and mine No. 8, 3 miles northwest of Herrin, are in the Herrin coal bed.

Mine No. 8.—Mine No. 8 produces about 2,500 tons a day. The coal is at a depth of 170 feet near the shaft and 7½ feet was mined in most of the workings. The return air came to the upcast in two main airways, one from the eastern part and the other from the western part of the mine, although there was a slight mingling of the ventilation far back in the workings. Little gas was found in the mine and most of it was in the top coal and never in the holes or undercuts. Some time previous to the date of sampling a small blower, which lasted two months, developed in the top in the second southeast entry. The east return, sampled at a point 195 feet east and 190 feet south of the shaft, carried 41,580 feet of air which contained 0.21 per cent methane, or slightly more than 87 cubic feet a minute, and 0.36 per cent carbon dioxide. The west return, sampled at a point 195 feet west and 190 feet south of the shaft, carried 36,190 feet of air which contained 0.14 per cent methane, or 51 cubic feet a minute, and 0.24 per cent carbon dioxide. The total volume of methane coming from this mine was about 139 cubic feet a minute.

Mine No. 7.—Mine No. 7, east of Herrin, was visited on March 18 and again on April 10, 11 days after mining had ceased. The output of this mine was about 2,000 tons a day. The coal is at a depth of 150 feet near the shaft and about 7½ feet was mined. The air in this mine was carried to the upcast by four principal airways, each one bringing the ventilation of about one-quarter of the mine. The tests of these returns gave the following results:

Methane and carbon dioxide in return-air samples collected in March and April, 1912, from mine No. 7.

Return.	Place where sample was taken.	Mar. 18, 1912.					Apr. 10, 1912.			
		Number of miners employed.	Volume of air per minute.	Proportion of methane in return air.	Proportion of carbon dioxide in return air.	Volume of methane per minute.	Volume of air per minute.	Proportion of methane in return air.	Proportion of carbon dioxide in return air.	Volume of methane per minute.
			Cu. ft.	*Per ct.*	*Per ct.*	*Cu. ft.*	*Cu. ft.*	*Per ct.*	*Per ct.*	*Cu. ft.*
Southeast, first to sixth south.	1,500 feet southeast of shaft.	55	21,680	0.13	0.70	6	2,700	0.12	0.80	3
Southwest, first to sixth south.	1,500 feet northwest of shaft.	35	4,810	.06	1.45	3	525	.04	.57	⅕
Northwest, second to sixth north and main west.	.....do.............	70	13,650	.18	.44	24½	11,050	.14	.36	15½
Northeast, first to sixth northeast and main east.	1,500 feet southeast of shaft (at junction of northeast and main east).	70	16,240	.21	.36	34	8,085	.22	.38	18
Total..........	....	230	56,380	......	......	68	22,360	......	......	37

The variations in methane emanation from the four quarters of this mine are somewhat notable. Seemingly the south half was producing less gas than the north half, due allowance being made for the smaller extent of the fresh workings. These differences continued after the cessation of mining, when the total methane emanation diminished to nearly one-half. If the large area of the mine be taken into consideration the amount of methane is remarkably small, and if the relative area of coal surface were made the basis of comparison the mine would show probably less methane per square foot than other mines of the same depth.

BUSH AND ROYALTON MINES.

The mines at Bush and Royalton illustrated the conditions in the Herrin coal field in the northwest corner of Williamson County and the adjoining southwest corner of Franklin County. The strata dip northeast, but at Bush there is a local synclinal flexure in the general monocline.

Bush mine.—The Bush mine is a moderately large one, about 250 miners being employed and the daily production being 1,500 tons. The coal is 7 to 9 feet thick and lies 118 feet below the surface at the shaft. No appreciable amount of gas had ever been noted in the mine. The most extensive workings were on the east and north sides. The main returns were east and west, but the currents from either side mixed somewhat far back in the mine. On March 25, 1912, the east return just east of the shaft carried 24,200 cubic feet of air per minute which contained 0.01 per cent methane and 0.22 per cent carbon dioxide. The main west return 350 feet west of the shaft carried 45,738 feet of air which contained 0.02 per cent methane and 0.34 per cent carbon dioxide. The volume of methane per minute was 2½ feet on the east side and 9 feet on the west side.

Royalton mines.—The south and north mines at Royalton reach the coal at depths of 212 and 315 feet, respectively, the measures having a moderately steep dip to the north. The coal is 9 feet thick. The south mine was a small one with an output of 250 tons a day, and the north mine produced about 1,600 tons a day. Both mines were visited on March 25, 1912.

The total return of the south mine sampled near the shaft carried 41,395 feet of air which contained 0.03 per cent methane, or 12½ cubic feet a minute, and 0.06 per cent carbon dioxide. No gas had ever been observed in making lamp tests in this mine. At the north mine a mile north, which was more than 100 feet deeper, gas appeared in the drill holes and in such volume at the working faces that bratticing had to be kept up close. The mine had been in operation only two years, so that there were no old workings. The returns were in two airways, each representing about half of the mine, and there were 90 miners on each side. The southwest return 100 feet southwest of the shaft carried 16,170 cubic feet of air per minute which contained 0.09 per cent methane, or 14½ cubic feet a minute, and 0.21 per cent carbon dioxide. The southeast return, sampled 350 feet southeast of the shaft, carried 6,000 feet of air which contained 0.36 per cent methane, or 21½ cubic feet a minute, and 0.10 per cent carbon dioxide. The reason for the greater volume of methane on the southeast side was not apparent.

HALLIDAYBORO MINE.

The Hallidayboro mine is far away from other mines in the Herrin bed. Its depth is 160 feet at the shaft and from 7 to 10 feet of coal was taken out. The output was about 1,200 tons a day. At the time of the author's visit on March 19, 1912, there were two main returns, one from the east, ventilating about three-fifths of the mine, and one from the west, ventilating two-fifths of the mine; 80 miners were employed in the east return and 45 in the west. The main east return 600 feet east of the shaft carried 23,100 cubic feet of air which contained 0.06 per cent methane, or 14 cubic feet a minute, and 0.16 per cent carbon dioxide. The main west return, sampled 600 feet west of the shaft, carried 19,200 feet of air which contained 0.08 per cent methane, or 15 cubic feet a minute, and 0.26 per cent of carbon dioxide. It will be noted that the volume of methane on the two sides of the mine was about the same. On both sides of this mine there were extensive old workings which had been mostly sealed off. Air from one of these sealed chambers contained considerable carbon dioxide. There are faults ranging from 1 to 30 feet in displacement. The coal near some of them contained considerable gas, which passed off gradually as the coal was taken out.

MINE AT GALATIA.

The conditions in the mine at Galatia were investigated because of the isolation of the mine and its relative depth. The mine was a small one, producing only about 150 tons a day. The coal, which is the Herrin bed, is about 6 feet thick and the depth of the mine at the shaft was 370 feet. The workings were about 800 feet wide by 1,500 feet long, or about 25 acres in extent. A little gas had been observed, especially in a steep place on the third east entry on the north side. The returns were in two courses, one from the south side, and another one from the north which ventilated about two-thirds of the workings.

The south return on February 28, just south of the shaft, carried 19,100 feet of air which contained 0.08 per cent methane and 0.10 per cent carbon dioxide. Seven miners worked in this air. Little gas had ever been noted on this side, which included many old workings. The main north return near the shaft carried 13,020 feet of air which contained 0.05 per cent methane and 0.06 per cent carbon dioxide. Seventeen miners worked on this side. The volume of methane was 15½ cubic feet per minute in the south return and 6½ cubic feet in the north return. As may be noted from the figures given above, 50 per cent more gas came from the part of the mine in which mining was less active.

CONDITIONS IN REPRESENTATIVE MINES IN HARRISBURG BED.

MINES ABOUT HARRISBURG.

In Harrisburg and to the north and south up and down the railroad, bed No. 5 is extensively worked by two companies. At Harrisburg the depth to this coal bed is 230 feet and there is a general rise of the beds to the south and a dip to the north.

O'GARA NO. 15 MINE.

The shallowest mine examined was the O'Gara No. 15, in which the top of the coal was only 58 feet below the surface, at the bottom of the shaft. The mine produced about 1,200 tons a day and 5 feet of coal was worked. The coal is overlain by 40 feet of almost impervious shale which should be expected to confine some gas. It was stated, however, that no gas had ever been noted in this mine.

The main returns were in two airways, one ventilating the west and the other the east workings, there being about 58 miners on each side. A small part of the air of the east return passed out in a crosscut. The remainder, sampled 250 feet southeast of the shaft, had a volume of 21,460 feet and it contained 0.01 per cent methane, and 0.09 per cent carbon dioxide. The main west return, sampled 150 feet south of the shaft, had a volume of 18,360 feet and contained no methane and only 0.04 per cent carbon dioxide. That the west return should contain no methane whereas the east return contained some was probably due to the fact that the east workings extended farther to the north down the dip where the coal is under thicker cover, the conditions otherwise being the same on both sides.

O'GARA NO. 7 MINE.

At the O'Gara No. 7 mine, a mile southeast of No. 15, the coal lies slightly deeper, the shaft being 76½ feet deep. The coal bed is 7 feet thick and a force of 90 miners produced about 800 tons of coal a day. The entire volume of return air was measured near the shaft on February 9, and found to be 20,520 cubic feet. It contained 0.03 per cent methane and 0.10 per cent carbon dioxide. These figures indicate an outflow of methane of only 6 cubic feet a minute from about 300 acres of workings.

O'GARA NO. 9 MINE.

The O'Gara No. 9 mine is a mile southwest of Harrisburg. The coal is at a depth of 156 feet and the beds dip gently to the northwest. The air of two main returns of the mine was sampled by S. O. Andros on August 18, 1912. Duplicate samples were collected in the main north entry 10 feet north of the hoisting shaft, where the volume was found to be 30,870 cubic feet per minute. It contained 0.18 and 0.14 per cent methane and 0.14 and 0.10 per cent carbon dioxide, results indicating an emanation of 55½ and 43 cubic feet of methane a minute, respectively. The main south entry, 25 feet south of the main hoisting shaft, carried 37,800 feet of air which contained 0.03 and 0.04 per cent methane or 11 and 15 cubic feet a minute, and 0.04 and 0.12 per cent carbon dioxide. The great difference in the amounts from these two entries is a noteworthy feature. The total volume of methane in the upcast averaged 62 cubic feet a minute. At the time of sampling the mine had an average daily production of 2,518 tons.

GARA NO. 3 MINE.

The O'Gara No. 3 mine is in Harrisburg and the coal, which is 6 feet thick, lies 239 feet below the surface at the shaft. The mine is old and large and reputed to be the most gaseous one in the region; there have been many small ignitions, which have burned men and mules. The daily production was about 2,100 tons. A dike of igneous rock crosses the mine about 500 feet southwest of the shaft and had been traced for 3,100 feet. It is 15 to 30 feet thick, stands vertical, and has converted the coal into coke for a distance of 6 to 8 feet on both sides. Another smaller dike 8 to 10 feet wide was found 2,600 feet southeast of the shaft and traced for 1,600 feet.

The air in the east return of this mine ventilated about twice the area traversed by the air in the west return. On February 10 the air of the main east return 700 feet east of the shaft was found to have a volume of 30,464 feet and it contained 0.09 per cent methane, or 27 cubic feet a minute, and 0.21 per cent of carbon dioxide. There were 132 miners in the workings ventilated by this air. Another return known as the first south entry off the east entry was sampled 150 feet due east of the shaft. It carried 4,560 feet of air, which contained 0.13 per cent methane, or 6 cubic feet a minute, and 0.10 per cent carbon dioxide. There were 90 miners in the workings on this split. A return entering by a manway 50 feet east of the shaft was found to carry 16,848 feet of air, which contained 0.12 per cent methane, or 20 cubic feet a minute, and 0.15 per cent carbon dioxide. This air came partly from the east and partly from the west and ventilated workings in which about 100 miners were employed. The main south return 200 feet southwest of the shaft was found to carry 27,936 feet of air, which contained 0.09 per cent of methane, or 25 cubic feet a minute, and 0.19 per cent carbon dioxide. The air in this return included a split of east air, which was largely from old workings and in part from about 20 fresh working places. The total volume of methane in the returns from this mine was 78 cubic feet a minute. The small amount from the first south entry off the east entry is a noteworthy feature.

O'GARA NO. 12 MINE.

The O'Gara No. 12 mine is 3 miles northeast of Harrisburg in the bottom of a basin in which the coal is slightly below sea level. The shaft depth is 421 feet and the coal worked is 5 feet thick. Gas is noticed in small amounts in places, but it has never caused much difficulty. The return air was in two main currents; one from the north workings, in which there was no mining, and the other from the south workings, where 60 miners were employed.

The main north return 150 feet north of the shaft had a volume of 17,856 cubic feet and contained 0.20 per cent methane, or 35 cubic feet a minute, and 0.15 per cent carbon dioxide. A small proportion of the south air was escaping into this part of the mine.

The main south return 150 feet south of the shaft had a volume of 18,291 feet and contained 0.02 per cent of methane, or slightly less than 4 cubic feet, and 0.05 per cent of carbon dioxide. The cause for the much greater amount of methane on the north side than on the south side was not apparent. It was expected that the larger amount would be found in the south return where 60 miners were working.

O'GARA NO. 1 MINE.

The O'Gara No. 1 mine is a mile north of the O'Gara No. 12 mine, and, owing to a rise of the strata, the coal is only 311 feet below the surface at the shaft. The mine, which is a relatively large one, was about 210 acres in extent and had a production of 1,400 tons. About 5¼ feet of coal was taken out. The return air came to the shaft in two principal airways, one from the south and the other from the north.

The main south return, sampled near the shaft on February 9, carried 18,870 cubic feet of air, which contained 0.61 per cent methane, by far the highest percentage noted in this region, and 2.07 per cent carbon dioxide, which was also exceedingly high. This air came from the southwest and east workings, where 37 miners were employed. A small part of the air escaped by other outlets. The air in the main north return from the northeast and west workings was sampled 225 feet north of the shaft. Its volume was 23,056 feet and it contained 0.36 per cent methane and 0.09 per cent carbon dioxide. About 200 men were mining coal in this air. The total volume of methane was 134 cubic feet a minute in the south return and 83 in the north return. The condition causing greater amounts of methane in this mine than in others in the vicinity was not evident unless it was the much greater area of coal exposed. The cause of the larger quantity in the south return than in the north return was not apparent.

MINES NEAR ELDORADO.

The mines in the vicinity of Eldorado work the No. 5 or Harrisburg coal, for in this region the No. 6 or Herrin bed is thought not to be sufficiently thick to be mined. At Eldorado bed No. 5 is about 400 feet below the surface or a few feet below sea level and lies in a shallow syncline with its axis extending nearly due north and south; its thickness is 4 feet 8 inches. Two mines at Eldorado were investigated, Nos. 8 and 10 of the O'Gara Co. The return air of the No. 11 mine was not sampled because it reached the upcast in many openings.

O'GARA NO. 10 MINE.

The O'Gara No. 10 mine is in the western margin of the village. The workings are extensive and 150 miners were employed. On February 10 a sample was taken of the air in the main north return near the overcast 300 feet north of the shaft. The return air had a volume of 28,944 cubic feet per minute and contained 0.35 per cent methane, or 101½ cubic feet a minute, and 0.16 per cent carbon dioxide.

The air in the main west return, which was sampled 350 feet south of the shaft, was partly from the same source as the air in the main north return, but included a return from some workings on the east side ventilated by a split of fresh air. It was estimated to carry about 80 per cent of the total ventilation from the west side of the No. 10 mine as part of the air was passing into the No. 11 mine through some holes on the east side. The volume of air in this west return was 53,460 cubic feet a minute and it contained 0.26 per cent methane, or 139 cubic feet a minute, and 0.10 per cent carbon dioxide. From these figures it appears that the returns from this mine were discharging about 250 cubic feet of methane a minute.

O'GARA NO. 8 MINE.

The O'Gara No. 8 mine was a new and relatively small one in the southern part of Eldorado about a half mile east of the No. 10 mine. The depth was about the same, but the area of workings was only about 160 acres. A prominent igneous dike divides the mine into two parts, east and west. Along the contact of the dike and the coal considerable coke has been formed by the heat, especially on the main east gangway which crosses the dike.

The return air in the mine was tested on February 10. The main east airway off the south return at a point 300 feet due south of the shaft was found to carry 15,750 feet of air containing 0.15 per cent methane, or 24 cubic feet a minute, and 0.11 per cent carbon dioxide. Thirty-four miners were working in this side of the mine. The west airway off the south return 300 feet southwest of the shaft carried 6,930 feet of air which contained 0.26 per cent methane, or 17½ cubic feet a minute, and 0.10 per cent carbon dioxide. This current was from the west half of the mine where 70 miners were taking down coal. As possibly half of the air on that side was escaping by side holes into the west return, it was difficult to ascertain the amount of methane in separate parts of the mine. The total emanation, found by testing the upcast, was 42 cubic feet of methane a minute.

NIGGER HILL MINE.

The Nigger Hill mine at Grayson southeast of Eldorado produced about 850 tons a day and 5½ feet of coal was worked. It was regarded as a moderately gaseous mine, for it showed considerable gas in places, especially on the east side. The depth at the shaft was 336 feet. A sample of air from the main east return was sampled 300 feet southeast of the shaft on February 10. This air ventilated about two-thirds of the working area, including old workings, and 52 miners were taking down coal at the time. The volume of air passing was 38,220 cubic feet a minute, and it contained 0.23 per cent methane and 0.10 per cent carbon dioxide. The air in the main west return, sampled 300 feet southwest of the shaft, had a volume of 28,296 feet and contained 0.10 per cent methane and 0.10 per cent carbon dioxide. The total volume of methane per minute was 88 cubic feet per minute in the east side and 28 feet in the west side, but no apparent cause for this difference could be found.

CONDITIONS IN REPRESENTATIVE MINES IN MURPHYSBORO BED.

MINES NEAR MURPHYSBORO.

In the vicinity of Murphysboro there is a group of mines that work the Murphysboro or No. 2 bed, the outcrop of which passes through the southern edge of the city. The bed dips to the north and east at a low angle, and at the Harrison mine it lies 160 feet below the surface. The mines about Murphysboro give off little methane, although traces are found in some of the workings even up to the vicinity of the outcrop. Three mines in this field were investigated, the No. 9, the Harrison, and the Blair No. 1.

NO. 9 MINE.

The No. 9 mine is on the flats of the Big Muddy River 2 miles northeast of the city. The coal here is at a depth of 108 feet. The production of the mine is about 1,400 tons, and 121 miners were employed at the time of the author's visit on March 4, 1912. The return air was sampled at two places. The first sample was taken in the main southwest return and represented the ventilation of all of the workings except those aired by a split that was sampled separately. This return from the main southwest carried 55,300 cubic feet of air, which contained 0.05 per cent methane and 0.11 carbon dioxide.

The split above mentioned, which joined the main return near the upcast was from east entries 1, 2, and 3 south, a district in which only eight miners were working. This split carried 30,800 cubic feet per minute of air containing 0.02 per cent methane and 0.05 per cent carbon dioxide. From these figures it would appear that the total outflow of methane in this mine was only 34 cubic feet a minute.

HARRISON MINE.

At the Harrison mine, which is 2 miles north of Murphysboro, the production was about 800 tons a day, and 65 miners were engaged. The mine includes a relatively large area of old workings. The total return near the fan was found to carry 65,755 cubic feet of air, which contained 0.03 per cent methane and 0.87 carbon dioxide. These figures indicate a total outflow of methane in the mine of about 20 cubic feet a minute; the great preponderance of carbon dioxide over methane in the return is worthy of note.

BLAIR NO. 1 MINE.

At the Blair No. 1 mine, which is a mile northwest of the Harrison mine, the coal is 135 feet below the surface. The production here is about 350 tons a day. There are two returns, each carrying the ventilation of about half of the mine. On March 5 the main east return carried 20,844 cubic feet of air, which contained 0.31 per cent carbon dioxide and no methane. Twenty-four miners were at work in the area ventilated by this air. The north return carried 18,120 feet of air, which contained 0.01 per cent methane and 0.33 carbon dioxide. Seventeen miners were working on the north side. These figures show that the mine was producing less than 2 cubic feet of methane per minute, whereas the carbon dioxide was more than 60 times as much.

PRESSURE OF GAS IN COAL BEDS.

In order to ascertain the pressure and in some measure also the volume of gas in the solid coal in place, tubes were inserted into holes in several mines. The mines selected for the tests were widely scattered over the area under investigation and represented considerable diversity of conditions. They were the Zeigler, United, Benton, Dering No. 11, Dering No. 18, Blackbrier, Hart-Williams, and B mines.

METHOD OF MAKING TEST.

The method used was nearly uniform in all cases. A part of the mine was selected, usually some advanced gangway heading with no adjoining workings, where the coal was most solid and presented the smallest area for escape of gas. A hole about 10 feet deep and about 3 inches in diameter was bored with an auger. Into this hole was inserted a 10½-foot length of ½-inch iron pipe, of which the last 3 feet was perforated. To the upper end of this pipe, which extended 6 inches beyond the face, a pressure gage was attached. The first 7 feet in the hole was tightly tamped with fire clay, which was carefully packed into place in small quantities at a time by a tamper consisting of a 2½-inch iron flange screwed to a 10-foot length of pipe of sufficient diameter to work outside of the tube to be set in place. The ½-inch tube carried a collar 3 feet from its inner end to hold the packing. In some holes the packing was finished with a few pounds of plaster and in nearly all holes was perfectly gas tight.

The principal features of one of these holes is shown in figure 32.

Many of the holes were gaseous while being bored, and the gas emanating would burn for several minutes. Boring and tamping were done as promptly as practicable to save as much gas and pressure as possible, and although some of the pressure was released before the valve could be set, and a certain amount of gas escaped, the losses were not a large proportion of the total. The coal adjoining the hole was not very permeable and the pressure and volume of the gas were finally brought to normal by the flow from adjoining parts a few inches distant, as was indicated by the fact that when the pressure in the gage was released, it would again rise to the original amount in greater or less time. The volume of gas was such that the hole would fill many times after it was emptied. The area of the walls of the 3-foot chamber in a hole 3 inches in diameter is 2½ square feet, and this factor was used in some of the calculations for the rate of gas emanation.

TESTS IN ZEIGLER MINE.

FIRST TEST

Two tests were made in the Zeigler mine—one on March 23, 1912, and another on April 7, 1912.

The tube was placed in a working face of a gangway in the extreme northeast corner of the mine, which was considerably in advance of any chamber workings. The place selected was a gaseous one, with a hissing feeder in the top which would ignite readily and burn indefinitely. The coal was porous and wet.

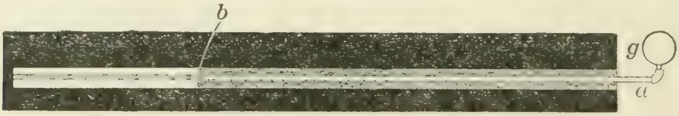

FIGURE 32.—Tube inserted in coal to ascertain pressure and flow of gas. The iron pipe *a* is 10½ feet long, including a 3-foot length of perforated pipe coupled at flange *b*, above which is 7 feet of tamping. The gage *g*, screwed on at the outer end, is an ordinary steam gage reading to 50 pounds.

When the pipe was set in place the gage recorded an initial pressure of 4½ pounds, and 1½ hours later the pressure had gradually risen to 10½ pounds. Four days later it was 12 pounds, and this pressure was sustained until April 7, when the gage was removed. The volume was small, but a 2-inch flame burned for some time. On resetting the gage the pressure rose to 12 pounds, and this was repeated twice in an hour.

SECOND TEST.

In the second test at Zeigler, on April 7, the tube was placed in a hole in the solid coal in the sixth gangway west off the C entry south, in the extreme southwestern part of the mine or the opposite side from where the first test was made. The tube was in advance of all workings and in perfectly solid coal. Of course the blasting of the gangway had caused some disturbance. In boring the hole much gas was found, which would burn vigorously. After tamping the pipe in place the gage went rapidly up to 25 pounds and then more gradually to 31½ pounds, which it recorded in 20 minutes. This pressure was sustained until April 13.

When the cock was opened, a moderate volume of gas came out and on closing it the pressure rapidly rose to 30½ pounds. During the next month the pressure increased to 33 pounds and then gradually decreased to 25 pounds, possibly because a slight leak appeared to have developed. The volume of gas at this stage was found to be small, but its flow was continuous, and it burned with a high flame.

TEST IN HART-WILLIAMS MINE.

On February 27, 1912, a tube was inserted in a hole in the solid coal in the extreme southeastern part of the Hart-Williams mine. The hole was 10 feet deep, the pipe used in this case was 1 inch in diameter, and there was 7 feet of packing, leaving 3 feet of perforated tubing in the inner end of the hole. The hole was placed horizontally in the middle of the coal bed. On the next day the gage registered about 12 ounces. On March 9 the gage was found to indicate a scarcely perceptible amount. The gage was replaced by a mercury column and the pressure was found to be 2 ounces. A sample of the gas was then drawn and on analysis it was found to contain 42.3 per cent of methane and 0.24 per cent of carbon dioxide. The gas was lighted after this sample had been drawn and it burned with an 8-inch flame for nearly an hour, when the cock was turned off. It was lighted again subsequently, but its volume was not determined.

TEST IN DERING NO. 11 MINE.

On March 28 a test was started to determine the pressure of methane in solid coal in the Dering No. 11 mine north of West Frankfort. The tube was set in a 10-foot hole in the end of the sixth southeast entry about a half mile southeast of the shaft. The pressure rose at once to 9½ pounds, and 2½ hours later it was 10 pounds. This pressure was sustained for several days. On April 13 one-half cubic foot of gas was drawn off and the pressure fell to 9 pounds; when another half foot was withdrawn, the gage reading was 7½ pounds; but when another one-half foot had been drawn, it was 8 pounds. Then after 10 minutes the pressure rose to 9½ pounds and finally to 10 pounds where it remained stationary until the gage was taken off a few hours later. A sample of this gas had the following composition:

Composition of gas from test hole in Dering No. 11 mine.

	Per cent.
Methane	31.19
Carbon dioxide	.29
Oxygen	16.51
Nitrogen (by difference)	52.01
	100.00

TEST IN DERING NO. 18 MINE.

On April 4, 1912, a test was started of gas pressure in solid coal at the Dering No. 18 mine northeast of West Frankfort. The place selected for the test was near a strong feeder. A 9½-foot hole was bored in the face of the first southwest entry where it yielded a strong flow of gas. When the tube had been set and the gage applied the pressure at once rose to 15 pounds, in 5 minutes to 20 pounds, and in another 5 minutes to 24½ pounds, where it remained stationary. On April 5 the gage reading was 23½ pounds; on April 6, 24½ pounds; and on April 7, 24¾ pounds, where it remained until the time of the author's return on April 11. When the cock was opened the pressure dropped to zero in about 40 seconds, but when the cock was closed, the pressure rose to 23 pounds in 15 minutes. A sample of the gas taken at this time was found to contain only 0.32 per cent of methane and 0.24 per cent of carbon dioxide. The drawing of the sample reduced the pressure to zero again but in a few minutes it rose to 6 pounds, where it remained a few hours until the gage was removed. The gas volume was small, for the removal of 1 cubic foot caused the pressure to drop to zero.

TEST IN UNITED MINE.

On March 22, 1912, a test was made of the pressure of gas in solid coal in the United mine east of Christopher. The hole was bored in the end of the sixth gangway north off the main entry east or in the extreme northeast corner of the mine. When the tube had been set the gas flowing from it could be ignited but when the gage was attached no pressure was developed. Observations at intervals to March 30 showed no pressure and finally, when the mercury gage was applied, the pressure was not perceptible. It was also impossible to collect any appreciable volume of the gas in a bottle arranged for measuring volume. However, when the gage was opened the gas burned with a flame 4 inches long; seemingly it would have continued burning for some hours and possibly for a much longer time.

TESTS IN BENTON MINE.

Early in April a test was made of the gas pressure in the coal at the Benton mine. A hole 9 feet deep was bored in the end of the seventh gangway west off the main south entry. The coal was very dry and solid and there was a slight hissing of gas in the face. No pressure was developed in a half hour, and on the author's return a week later there was still no pressure showing in the steam gage, nor did a mercury gage show any. No gas came from the cock when it was opened.

Another tube was set in the coal on May 4 by the mine superintendent. It was set in a hole 9½ feet deep, 6½ feet being well tamped. The hole was in the fifth gangway south off the seventh west entry south. The pressure was 16 pounds, with a small leakage around the tube. After this leak had been closed the pressure rose to 16½ pounds, which was sustained until May 13 when the gage was removed.

TESTS IN CHICAGO & CARTERVILLE CO. "B" MINE.

Two tests were made of gas pressure in the solid coal in the Chicago & Carterville Co. "B" mine, 3 miles northeast of Herrin.

The first test was made in the fourth heading west off the first gangway north off the main east entry in the end of a working with no chambers in the vicinity. Gas was hissing from the face at the place selected, which was regarded as very gaseous. The hole was like the others, 10 feet deep with 3 feet of perforated pipe at the end and 7 feet of tamping. The gas burned with a 1½-inch flame from the end of the pipe before the gage was set. The gage did not move at first but in a few hours pressure was manifested and the next day was 7 pounds. The pressure was sustained at 7 pounds the first week and then increased to 7½ pounds, where it remained until June 3 when the gage was removed.

Another gage was set in the end of the second gangway south off the west entry. The coal was wet but solid. No pressure was developed at first but after 24 hours the gage showed 2½ pounds and this was sustained until June 3 when the gage was removed.

TEST IN BLACKBRIER MINE.

On April 3, 1912, a tube was set in the solid coal at the end of the most advanced gangway in the Blackbrier mine. The direction of the hole was west, parallel with the principal jointing. The hole showed no gas and the gage gave no indication of pressure. A week later it was found that there was still no pressure, even to a mercury gage, and no gas was released when the tube was opened.

COMPARISON OF RESULTS IN DIFFERENT MINES.

A tabulation of the initial pressures recorded soon after closing the gage, and the pressures developed at later periods, is given in the table following.

Comparison of pressures of gas in solid coal in 11 mines.

Mine.	Place where test was made.	Initial pressure.	Later pressure.	Time between readings.	Remarks.
		Pounds.	*Pounds.*	*Days.*	
Hart-Williams	Southeastern part	¾	⅛	10	42.3 per cent methane, moderate volume.
Dering No. 11	Southeast entry	9½	10	6	31.2 per cent methane, moderate volume.
Dering No. 18	Southwest entry	24½	24¾	7	Air with 0.32 per cent methane, small volume.
United	Northeast corner	0	0		Gas would burn.
Zeigler	do	10½	12	4	Volume small.
Do	Southwest corner	25	33	30	Volume very small.
Benton	Seventh gangway west off main entry south.	0	0		No gas.
Do	Fifth gangway south off seventh entry southwest.	16	16½	9	Considerable gas.
Chicago & Carterville Co. "B" mine.	Northeast section	7	7½	8	Do.
Do	Southwest section	0	2½	1	Small volume.
Blackbrier	End of west gangway	0	0		No gas.

VARIATIONS IN VOLUME OF GAS DURING MINING.

For the purpose of ascertaining the variations in the amount of methane at different times during periods of active mining, a second series of samples was taken in five of the mines previously visited, in which mining had been steadily carried on in the meantime. They were all mines that gave off considerable amounts of gas and were large producers.

The results obtained from the two sets of samples are compared in the following table:

Differences in amounts of methane from working mines at different times.

Mine.	Date of sampling.	Volume of methane per minute.							Daily production.
		Total upcast.	North return.	West return.	South return.	East return.	Northwest. return.	Northeast. return.	
	1912.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Tons.*
Hart-Williams	Jan. 15	90				64			2,400
Do	Feb. 14	133				65			2,400
Benton	Jan. 16	202	95	44	53				2,100
Do	Mar. 9	194	68½	74	52				2,100
Zeigler	Feb. 2	153	93		60				2,300
Do	Mar. 23	181	154		27				2,300
Dering No. 11	Jan. 19	[a] 204		83		82	33	21	1,500
Do	Mar. 28	[a] 271		91		67	32	24	1,500
Wilmington-Star	Jan. 19	171	86		86				1,500
Do	Mar. 28	212	119		93				1,500

[a] Shaft sample; the other totals are sums of separate returns. The cause of the discrepancy in the Dering No. 11 mine on Mar. 28 is not known.

These results show marked variations in the methane emanation not only in the total upcasts but in the separate returns, which were undoubtedly caused by variations in the amount of gas in the coal as mining progressed, increasing in some districts and diminishing in others without relation to the tonnage removed which continued nearly uniform.

EFFECT OF CESSATION OF MINING ON VOLUME OF METHANE.

All the mines were closed by a strike on April 12, 1912, and mining was discontinued for a month. Advantage was taken of this opportunity to ascertain the effect of no mining on the amount of methane by resampling the returns. Certain mines visited presented considerable variety as to size, depth of cover, and location, all in the Herrin coal bed. The observations made are given in the following table, together with the amount of methane found in previous visits:

Volumes of methane given off while mines were shut down, compared with volumes during operation.

Mine.	Return.	Volume of methane a minute.		Daily production of mine.	Depth at shaft.
		During operation of mine.	After mine suspension 5 to 15 days.		
		Cu. ft.		*Tons.*	*Feet.*
Benton	Total upcast	202 -194	164	2,400	630
Do	Main north	95 - 68½	40		
Do	Main west	44 - 74	82		
Do	Main south	53 - 52	42		
Zeigler	Total upcast	153 -181	78		418
Do	South	60 - 27	22	2,300	
Do	North	93 -154	56		
Paradise	Total return	101	41		380
Dering No. 11	Total upcast	204 -271	177	1,500	500
Do	Main west	83 - 91	57		
Do	First northwest	[a]33 - 32	27½		
Do	Main east	82 - 67	68		
Do	Third northeast	21 - 24	20½		
Dering No. 18	Total returns	49	37½		512
Do	Main south	11	15	500	
Do	West off south	19	10		
Do	Main north	19	12½		
Wilmington-Star	Total returns	172 -212	130		440
Do	South	85½- 93	69	1,200	
Do	North	86½-119	61		
Standard	Total return	56	62		276
Do	East	37	32	1,000	
Do	West	19	30		
Blackbrier	Total return	55½	31	1,100	185
Big Muddy	Total return	14½	3⅕	1,500	100
Do	East	11½	3		
Do	West	3	⅕		
Hemlock	Total returns	9½	15		155
Do	East	2½	8	700	
Do	West	7	7		
Taylor No 2	Total returns	12	0	1,500	140
Do	West	6½	0		
Do	East	5½	0		
Chicago & Carterville Co. "A" mine.	Total returns	227+	128½	2,100	186
Do	Main north	83	21		
Do	Third west south	8	14		
Do	First east north	33	52		
Do	Second west south	35	27		
Do	Main south	68+	14½		
Chicago & Carterville Co. "B" mine.	Total returns	101	140	1,500	247
Do	Main east	47	42		
Do	Main west	54	98		
Big Muddy Coal & Iron Co. No. 7.	Total returns	67½	37	2,000	150
Do	Southeast ¼	6	3		
Do	Southwest ¼	3	⅛		
Do	Northeast ¼	34	18		
Do	Northwest ¼	24½	15½		

[a] Not being mined at time of sampling.

Nearly all these mines showed a marked diminution of volume of methane after mining had been suspended. In the Taylor No. 2 mine the amount dwindled to zero, in the Big Muddy mine from 14½ to 3½ cubic feet a minute, in the Zeigler mine from 181 to 78, in the Wilmington-Star mine from 212 to 132, and in the "A" mine from 227 or more to 128½. In the Chicago & Carterville "B", Standard, and Hemlock mines the volume increased for some unknown reason. The total emanation in the mines given in this list was 1,551 cubic feet of methane a minute at the times of sampling in January, February, and March, whereas in April, after the shutdown, the total volume had diminished to 1,048 cubic feet, or about 32 per cent less.

RATE OF ESCAPE OF GAS FROM ILLINOIS COAL.

A few tests have been made to ascertain the amount of gas contained in samples of coal from southern Illinois with results very similar to those obtained from samples from other regions. Porter and Ovitz [a] made some extended tests of the rate of escape of gas from samples of coal from the O'Gara No. 9 mine near Harrisburg and from the Hart-Williams mine, at Benton, Ill., and also observed the capacity of the samples for oxygen absorption.

The mine samples weighed about 32 pounds and represented the clean, fresh working faces from top to bottom. The material was first crushed to pass through a ½-inch screen and then placed in a 5-gallon bottle which was sealed as quickly as possible, the whole operation taking about an hour. During the tests the coals were kept in the laboratory of the Bureau of Mines at Pittsburgh at temperatures varying from 54° to 90° F. The sample of Harrisburg coal was connected with an air supply by means of an air-inlet tube which extended from a reservoir of air to the center of the bottle through a hole in the cork. The bottle of Benton coal was connected with an oxygen supply admitted at the top and the gas was drawn off at the bottom into a reservoir. The quantity of air or oxygen admitted was measured and the gas was measured and analyzed. The results are given on the following page.

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[a] Porter, H. C., and Ovitz, F. K., The escape of gas from coal: Technical Paper 2, Bureau of Mines, 1911, 14 pp., 1 fig.

Gases given off and oxygen absorbed by two Illinois coals.

Place where coal was obtained.	Weight of sample.	Period of time.	Gas given off per cubic foot of coal.		Oxygen admitted per cubic foot of coal.[a]	Oxygen absorbed per cubic foot of coal.
			Methane.	Carbon dioxide.		
	Pounds.		*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
O'Gara No. 9 mine, near Harrisburg.	36	First 4 days	0.218	0.001	0.148	0.145
		Next 24 days	.340	.001	.148	.145
		Next 31 days	.217	.003	.650	.610
		Next 30 days	.125	.000	.244	.235
		Next 153 days	.372	.030	1.553	1.520
		Next 31 days	.029	.019	.360	.343
		9 months	1.083	.054	2.955	2.853
Hart-Williams mine, near Benton.	27	First 15 days	0.763	0.010	0.217	0.220
		Next 15 days	.113	.000	.490	.494
		Next 62 days	.577	.019	3.587	3.532
		Next 30 days	.107	.018	1.169	1.113
		Next 31 days	.065	.007	1.652	1.576
		Next 365 days	.196	.079		
		17 months	1.821	.133	7.115	[b]6.935

[a] Oxygen from air in Harrisburg coal and 95 per cent pure in Benton coal, so that results are not comparable.
[b] Total for 6 months.

The irregularities in oxygen absorption were due to the irregular rate of admission. Doubtless much more would have been absorbed if the admission had been regular.

In an investigation of occluded gases in Illinois coals, Barker[a] tested a number of samples of coal from the area discussed in this bulletin. They had been partly air-dried and were placed in jars with much air. One sample from the Davis mine near Duquoin and another from the Big Muddy mine near Marion gave off no methane, one from the O'Gara No. 8 mine near Eldorado gave off 0.38 volume, and one from the Squirrel Ridge mine near Herrin gave off 0.17 volume.

Samples of drillings were collected at intervals from a horizontal drill hole bored for making pressure tests in the Hart-Williams mine. The first sample was taken at a depth of 3 feet, the second at 6 feet, and the third at 10 feet. They were sealed in tin cans. A month later they were tested in the laboratory of the Bureau of Mines in Pittsburgh, with the results following.

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[a] Barker, Perry, The occluded gases in Illinois coals: Ill. Geol. Survey Bull. 14, 1908, pp. 204–210; Trans. Am. Inst. Min. Eng., vol. 40, pp. 24–31, 1909.

Results of analyses of gas given off by coal samples from bore hole in Hart-Williams mine, Benton, Ill.

[G. A. Burrell, analyst.]

Sample.	Gas given off.			
	Methane.	Carbon dioxide.	Oxygen.	Nitrogen.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1	21.35	Less than 0.1	2.62	77.02
2	5.80	do	2.52	91.67
3	10.60	do	2.18	87.21

These results throw no light on the volumes given off; moreover, considerable air was taken in when the samples were placed in the can. The figures, however, show that methane was evolved, probably in different amounts, from the three samples and that some of the oxygen had been absorbed.

RELATION OF METHANE EMANATION TO DEPTH.

It is well established that in most areas where the coal is near the surface little gas remains in it, and in general up to a moderate depth the deep mines are more gaseous than shallow ones. The escape of gas from the coal to the surface has been in progress for an extremely long time and even from deep-seated beds there has been some loss in this way. An important factor affecting the rate of escape is the relative permeability of the strata overlying the coal, and the degree of permeability depends not only on the texture of the rock, but also on the extent to which faulting and joint crevices are present. A bed of gaseous coal near the surface overlain by sandstone would be likely to lose much of its gas, whereas a cover of shale or clay would greatly impede the escape of gas.

Interstitial moisture also impedes the movement of gas through the strata, but the extent of its influence is not well known. Fracturing of the strata is also an important factor, for the gas travels along fault planes and joint cracks. A coal bed lying several hundred feet below the surface is usually overlain by alternations of the clays and sandstones that compose the coal measures. As much of this material is only slightly permeable, there is with increasing depth a proportionate general increase in the amount of gas confined in the coal; but, as shown by figure 33, the relation is not a close one and this increase ceases below a certain depth. The table on page 224 shows the relative volumes of methane given off by mines of southern Illinois, arranged in order of their depth, and also the amount in relation to daily coal production from each mine.

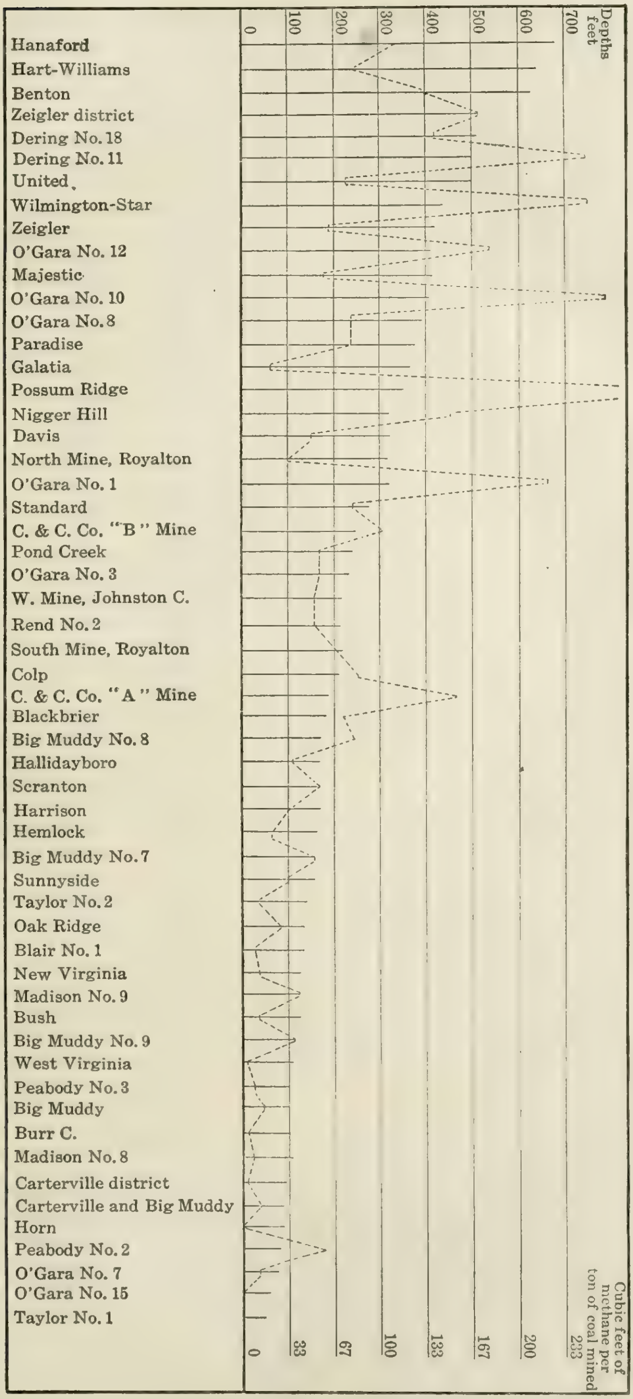

FIGURE 33.—Relation between depth of mines and amount of methane per ton of coal mined in southern Illinois.

Total methane emanation from southern Illinois mines arranged in order of their depth.

Mine.	Depth at shaft.	Methane.		Daily production of coal.
		Volume per minute.	Volume per ton of coal mined.	
	Feet.	*Cu. ft.*	*Cu. ft.*	*Tons.*
Hannaford	696	75½	109	1,000
Hart-Williams	640	90–133	53– 80	2,400
Benton	630	194–202	133–138	2,100
Zeigler district	517	241	173	2,000
Dering No. 18	512	49	141	500
Dering No. 11	500	204–271	195–260	1,500
United	500	220	74	4,300
Wilmington-Star	440	172–212	205–255	1,200
O'Gara No. 12 [a]	424	39	186	300
Zeigler	418	153–181	95–113	2,300
Majestic	412	165	110	2,150
O'Gara No. 10 [a]	411	250	313	1,150
O'Gara No. 8 [a]	407	42	81	750
Paradise	380	101	81	1,800
Galatia	365	22	21	150
Possum Ridge	357	391½	563	1,000
Nigger Hill [a]	325	116	196	850
Davis	320	96	98	1,400
North mine, Royalton	315	36	33	1,600
O'Gara No. 1 [a]	311	217	222	1,400
Standard	276	56	81	1,000
Chicago & Carterville Co. "B" mine	247	101	97	1,500
Pond Creek	240	36	53	1,000
O'Gara No. 3 [a]	233	78	54	2,100
West mine, Johnston City	220	105	53	2,800
Rend No. 2	215	73	53	2,000
South mine, Royalton	212	12½	72	250
Colp	210	24	86	400
Chicago & Carterville Co. "A" mine	186	227+	156	2,100
Blackbrier	185	55½	73	1,100
Big Muddy No. 8	167	139	80	2,500
Hallidayboro	160	29	35	1,200
Scranton	160	25	55	650
Harrison [b]	160	20	36	800
O'Gara No. 9 [a]	156	62	36	2,515
Hemlock	155	9½	20	700
Big Muddy No. 7	150	67½	49	2,000
Sunnyside	150	42½	31	2,000
Taylor No. 2	140	12	11	1,500
Blair No. 1 [b]	135	2	8	350
Oak Ridge	135	18½	25	1,100
New Virginia	120	15½	21	1,100
Madison No. 9	120	69	40	2,500
Bush	118	11½	11	1,500
West Virginia	108	2½	3	1,200
Big Muddy No. 9 [b]	108	34	35	1,400
Peabody No. 3	100	14	8	2,400
Big Muddy	100	14½	14	1,500
Burr C	100	4½	4	1,500
Madison No. 8	100	9½	8	1,500
Carterville district	96	3	3	1,450
Carterville & Big Muddy	86	8	11	1,000
Horn	80	0	0	....
Peabody No. 2	80	55+	66	1,200
O'Gara No. 7 [a]	76½	6	11	800
O'Gara No. 15 [a]	58	2	3	1,200
Taylor No. 1	55	1½	2	1,000

[a] Harrisburg bed. [b] Murphysboro bed.

PROBABLE INCREASE OF GAS IN DEEPER OR LARGER MINES.

A question of practical importance considered in the investigations in Illinois concerns the amount of gas to be expected in the deeper parts of the field, as yet undeveloped. The danger of gas and the added expense that must be incurred in combating large volumes of it are important considerations affecting the development of the coal in many areas. The results of this investigation show that the deeper mines are not likely to find more gas than has been encountered in those of moderate depth. It is found that below 150 or 200 feet beneath the surface depth is not the principal factor affecting the volume of gas, but that variations in the character of the coal cause differences in the amount given off. This regional variability also indicates that a mine with low gas volume must not be conducted with a false sense of security, for a gaseous district may be entered at any time and the gas become dangerous on very short notice. Accordingly equipment should be provided capable of coping with sudden developments of greatly increased volumes of gas.

Another important consideration is whether or not there will be an important increase in gas volume as the workings become larger and the area of exposed coal surface consequently increases. Several of the companies have already extended their mining operations over nearly all of the area owned by them, and the increase of total gas volume appears not to have increased proportionately to the area worked. This result is due to the fact that the larger part of the gas has been given off from freshly exposed coal in the working faces during the mining so that the old pillars do not contribute any large proportion of the total methane emanation. As mining progresses in the larger properties the disposition will be not to extend the workings to great distances, but to move to the adjoining area and sink a new shaft, as the item of long underground haulage is an important one in the cost of production.

SUMMARY OF CONDITIONS OF OCCURRENCE OF METHANE.

Although many observations have been made as to the conditions under which explosive gases occur in coal and are given off by it, some of the causes of the variations in the character, amount, and pressure of such gases are still unknown. In this chapter are summarized the principal facts developed by the investigations in Europe and this country, including the author's own observations in Pennsylvania and Illinois.

COMPOSITION OF GAS GIVEN OFF BY COAL.

The gas given off by coal in mining as well as in laboratory experiments under different conditions shows considerable range in composition. Although methane is the principal component its proportion varies not only in gases in the mine but in gases extracted from coal samples under various conditions. In most cases the gas given off by coal and by blowers contains more than 80 per cent of methane, and in places the methane is nearly pure. Carbon dioxide, nitrogen, and oxygen, with proportions varying greatly, are the other principal ingredients of the gas from fresh coal. The variations in composition doubtless indicate a complex chemical process in the development of the coal, which is further indicated by the great variation of volume of contained gases in the coal from bed to bed and from place to place in the same bed. These variations have not as yet been connected with visible characteristics in the coal, and they appear to be entirely independent of the chemical constitution of the coal, reported as "fixed carbon," "volatile combustible matter," etc.

The gas given off by coal at different stages of exposure and in fragments of various sizes also shows great variability. In the mine there is considerable difference between the composition of gas from blowers and from the fresh face and that from old pillars and ribs, and in the laboratory the degree of pulverization and the duration of tests materially affect the composition of the gases obtained. Doubtless air absorption with resulting oxygen combination has much to do with this phase of the problem.

MANNER OF ESCAPE OF GAS FROM COAL.

Seemingly gas escapes from coal by percolating through the pores or interstices between the coal grains and also through fissures great and small. The principal controlling factors under these conditions therefore are, (1) texture or size of grain, (2) extent and size of fissures, and (3) amount of pressure forcing the gas outward. Gas escapes most rapidly when the mining operation reaches a fissure or a body of shattered coal that constitutes a reservoir under high pressure and when such a body of coal is thrown out in such large quantity that much of the gas is given off at once. Outbursts of this character have caused numerous accidents, some with considerable loss of life. Very careful study of these outbursts has not revealed any definite law of occurrence and no dependable means has been found for detecting their proximity or for preventing them. They happen most often in zones where the strata are crushed or disturbed or in places where the coal thickens and thins, but they are not connected with any peculiarities of the coal that are discernible according to our present knowledge. Bodies of softer, more porous coal inclosed by harder coal are naturally very likely to be a source of outbursts, for they may contain a large volume of gas dammed back by the hard coal. The likelihood of increased gas emanation and accumulation from squeezes and other local movements in mines is well recognized, for ordinarily these accidents not only cause deep fissuring but interfere with ventilating currents.

PRESSURE OF GAS IN SOLID COAL.

The pressure of gas in the solid coal has been determined in England, France, Belgium, Austria, and Illinois with results presenting anomalous variations. The tests by Wood in England showed pressures ranging from 176 to 461 pounds in the deeper test holes and, though in several tests the pressures were related to the depth of hole, there was great variation between closely grouped localities in each mine and between two beds in different mines. In Austrian mines the variation was from 82 to 142½ pounds. The test in two inclined beds in the Belle-Vue mine in Belgium, made in a heading 2,264 feet below the surface in holes that reached the coal from a heading in rock, showed pressures of 325 to 637 pounds. Tests made when this heading was extended into the coal showed little immediate fall of pressure, in most cases proving that pressure was sustained for a considerable time by the very imperfect permeability of the coal. This condition also accounts for the slowness with which the higher pressures are manifested, because the adjustment of equilibrium of pressure takes place slowly where the permeability is slight. Several observers have noted that the highest pressures are not found in places where the most gas is noticeable in the workings, and this was the case in headings where the author made pressure determinations in southern Illinois. In nearly all pressure tests it was found that when the cock was opened so that pressure was lost, it was quickly regained when the cock was closed. Further evidence of exceedingly slow permeability of the solid coal to gas was afforded by the tests in the Beaulieusart mine in Belgium. In that mine, with pressures of 120 and 187 pounds in two holes, several gas and coal outbursts only a few yards distant caused only slight oscillations in the pressure in one hole, although they finally drew off the pressure in the nearer hole. In the test holes made by Simon and Morin in the Liévin mine, France, which showed pressures of 10 to 105 pounds, the places giving off the most gas showed low or moderate pressures.

The observations reported by Ghysen showed that pressure was not closely related to obvious gas emanation for in only slightly gaseous workings at Grand Hornu and Marihaye the pressures were 60 and 225 pounds, and in a very gaseous bed in the Agrappe mine the highest pressure observed was less than 15 pounds.

In the many test holes in St. Étienne it was found that in general the pressure and gas volume increased regularly with depth of holes, but the highest pressure was only 44 pounds, even in holes 23 feet deep.

Holes to ascertain the possibility of draining the gas from solid coal proved their entire uselessness on account of the small surface of coal exposed. The pressure of water in the strata overlying coal beds is probably a factor of some importance in gas pressure and also the weight of the stata which is very great in a mine 2,000 feet deep.

The idea of Wood and Mallard that there is a precise ratio between pressure and depth of hole is not sustained by most observations. The local variations in pressure show that the gas is irregularly distributed in coal beds even in short distances, but of course in general the pressure gradually increases as the solid coal is penetrated beyond the influence of fissures and ordinary outflow to the surface, and it attains a maximum some distance from the face. All the investigations have shown that this maximum also varies greatly in the same bed from place to place. Pressures observed in the Illinois coal field ranged from a few ounces to 33 pounds and in four headings in solid coal no pressure at all was indicated. Pressure from a blower in a Pennsylvania anthracite mine was found to be 45 pounds to the square inch.

The pressure tests indicated that in general high pressure, if present at all, is manifested where the coal is most compact, and owing to leakage near the face the higher pressures are found only in the deeper test holes, the depth necessary for a high pressure depending on compactness of the coal.

VOLUME OF GAS IN COAL.

The volume of gas in coal as shown by the amounts given off by mining a definite amount of coal and by laboratory tests of coal samples is as variable as the pressure. Variation in the original volume is no doubt related to the organic character and history of the coal and to other factors not yet ascertained. In many cases in the mines the coal containing the most gas, or gas with highest pressure, does not have the most gaseous workings, or gas bodies dangerous to the miners, for a large volume may be given off so regularly and for such a long time that its outflow is less noticeable than the rapid emission of a relatively much smaller amount. Moreover, we can not know the original volume of gas in different coals, for varying amounts have been lost by escape through overlying strata as well as in opening and mining. Some of the tests have shown that in many instances less total gas a day is given off in workings showing marked accumulations of gas in the faces, or from feeders, than in workings in which the outflow is general but so gradual that its presence is not suspected when the ventilation is adequate.

The conditions under which large volumes of gas are contained in the coal, such volume as 1 to 1 and 3 to 1 or more, have not been determined. Possibly the gas is locked in some loose chemical combination, dissolved as salt dissolves in water, or condensed as in porous charcoal, but undoubtedly it fills the pores and crevices in which it is condensed considerably by pressures of 50 to 500 pounds to the square inch. The variation in volume of methane emanation in mines has been studied in various mines in Europe and was closely considered in the author's series of observations in the mines in Pennsylvania and Illinois. If only the deeper workings where gas has had little chance to escape to the surface be considered, there are found great differences in the amount of gas given off by mining in different beds and different workings in the same bed. As the investigations progressed it was soon found that these differences were connected neither with variations in structure of the measures nor with cover below the first few hundred feet, but were local features in the coal. One excellent instance of this was in the 5-foot workings at the Lance mine, Plymouth, Pa., where the chambers on the east side were giving off 400 cubic feet of methane a minute and those on the west side were yielding 70 cubic feet, with area of coal exposed and other conditions closely similar on both sides, except that on the less gaseous side nearly twice as much coal was being mined. A similar difference but in less degree was found in the Hillman workings next above.

Most of the published facts relating to mine gas give proportions of methane in the return only; others indicate the volume from the mine or from different returns, and a few observers calculate the volume to the ton of coal mined or to the area of coal exposed. Some of the investigations show the differences in amount of methane given off under different conditions of mining, periods of cessation from mining, and changes of atmospheric pressure. Many figures of volume of methane carried by air returns in a given time demonstrate regional variations that indicate that some districts or some mines are especially gaseous and that generally in a mine certain beds or certain workings in a bed give off much more gas than others. In places there is close ratio between gas volume and amount of coal mined or area of coal surface exposed. This latter relation is exceptional, however, and the volume of gas varies from place to place without connection with any special properties of the coal known to us at present.

OUTFLOW AT CERTAIN MINES.

Among mines with large outflow of gas those near Wilkes-Barre, Pa., lead with 2,000 to 3,500 cubic feet a minute, and some of the more fiery of the Prussian mines range from 400 to 625 cubic feet. Figures of this character have to be considered in connection with extent of workings and tonnage of output and the data for these factors are given in but few instances. In the Saarbrücken basin the volume varied from 16½ to 2,160 cubic feet to the ton of coal mined; in the gaseous mines near Wilkes-Barre the rate ordinarily ranged from 2,000 to 3,850, with an average of about 1,500 cubic feet a ton; in some Austrian mines it ranged from 519 to 7,469 cubic feet; at Gemeinschaft and Ath-Gouley the rate per ton was 409 to 3,360 cubic feet, and in two fiery French mines the figures given are 883 and 1,377 cubic feet. In the deeper mines in southern Illinois the amounts varied from 50 to 260 cubic feet per ton. In some mines, however, the amount did not diminish very materially when mining was stopped for a time, especially in certain workings in mines near Wilkes-Barre and in Austria, but in others the diminution was noticeable, even the Sunday cessation making an appreciable difference. Fresh face workings yielded vastly more methane than workings in pillars. The amount of gas per 1,000 square feet of coal surface determined at a few mines near Wilkes-Barre and Scranton ranged from 0.23 to 5 cubic feet a minute, with amounts of 1.67 to 5 cubic feet from workings that were especially gaseous. In the mines at Liévin the range was from 2.3 to 14.7 cubic feet. The coal in test holes at St. Étienne gave off gas varying in volume from 20 to 88 cubic feet a minute, calculated for an area of 1,000 square feet, the amount in general increasing as the pressure increased. In test holes made by Wood, the maximum volumes calculated for 1,000 feet of area ranged from 4 to 100 cubic feet a minute without relation to pressure.

INFLUENCE OF TEMPERATURE ON METHANE EMANATION.

Many tests have been made to ascertain the amount of methane given off by coals at ordinary temperature and at 212° F., in a vacuum, in the presence of various other gases, and in different periods of time. The tests have yielded a wide range of results without revealing any special relations. The volumes of gas and the percentages of methane differ greatly with different coals and in some mines from nearby samples of the same bed. Ordinarily, with increased time, there is increased volume as tests of six months and longer have shown, and volume or celerity of emanation increases in proportion to the fineness to which the sample is ground. The relative volume of gas to coal ranged from 0.1 to 8 times at 212° F., and to 5.5 times at ordinary temperature, but the average amount probably falls below 1 under ordinary temperature. A sample of anthracite from Pennsylvania gave off nearly four volumes in a long test. Nearly all kinds of coals, according to our present ideas of classification, showed great range in gas volume. Samples of certain coals from especially gaseous chambers in mines gave off only moderate volumes of gas when tested in the laboratory, but no determinations have been made as to what extent coals testing high in gas cause more gaseous workings than the others.

INFLUENCE OF COMPOSITION OF COAL ON GAS EMANATION.

Doubtless the local differences in gas content were related to variations in putrefactive and other conditions under which the coal was formed, such as variations in character of the vegetable deposits and the nature and time of deposition of the overlying strata. Many of the analyses given by European writers show no relation between methane and composition of the coal, as the latter is usually reported, and we know that lignite, anthracite, and bituminous coal are closely alike as to their methane component and its variation from place to place.

Possibly when we can ascertain the organic components of coal, and when gas distribution is studied in that connection, we shall find certain relations, especially if knowledge is available as to the original organic chemical history of coal development.

The origin of methane in coal has been considered by many writers and although it is evident that the gas is a product of the decomposition or molecular rearrangement of the original organic matter, the precise nature of the chemical process has not been ascertained. It is possible that somewhat similar amounts of gas were given off in the formation of all coal and the retention of the methane has depended on conditions of deposition and cover. On the other hand, it is likely that different plant components may have developed very different amounts of gas in their conversion into coal, and temperature, moisture, and rate of accumulation may have been factors. If a certain coal contains many times its volume of gas in voids that can not be more than 10 per cent of the volume of the mass there must be great condensation under high pressure or some peculiar molecular relation that we do not understand. Tests of powdered coal prove that a long time is required for all the gas to leave the coal, however great the quantity liberated at first exposure.

ATMOSPHERIC INFLUENCES.

In this report there can be presented only a part of the extensive literature on the influences of barometric changes on gas emanation. Although some of the investigations appear to show that such relation has no practical importance, others indicate that a largely increased volume of methane results from marked diminution of atmospheric pressure, especially in returns draining old workings. The argument frequently advanced that atmospheric pressure can not affect the emanation of gas from the solid coal because of the high pressures as shown in test holes is entirely fallacious for whatever the pressure may be 10 feet in the coal it must become zero at the face where the gas actually escapes. The curves drawn by Galloway, Chesneau, Koehler, Schöndorf, Nasse, Hilt, Broockman, and Morin undoubtedly indicate a close relation between methane emanation and atmospheric pressure in the mines that were tested, and naturally it is to be expected that this relation will be found in other mines of the same character. However, it appears likely, as maintained by most of the French and English engineers, that the increased emanation at the time of low barometer can not be a source of danger in well-ventilated mines. Without suitable ventilation carried to gaseous working faces there is danger of explosions at any time, and if the danger is slightly greater with diminished atmospheric conditions it is merely one of degree. There are in most gaseous districts many chambers that rapidly fill with gas if the air current fails owing to open doors or lack of suitable bratticing.

RELATION OF METHANE ACCUMULATIONS TO EXPLOSIONS.

Deductions based on statistics of explosions in mines as related to the weather or other factors are misleading for many such explosions have not been caused by increased methane emanation. In the first place we now know that many of the larger explosions were propagated mainly by coal dust, and in the second place most explosions are started by accidental ignition, generally without connection with any unusual gas outflow in the workings as a whole. Fortunately many gas outbursts and local gas accumulations are not ignited because of increased precautions. The accumulation of local bodies of explosive gas is of every-day occurrence in parts of many mines and in those places carelessness of an individual may cause an accident without any connection whatever with atmospheric pressure, temperature, humidity, earth tremors, or the general volume of methane in the mine. Many of the most dangerous gas bodies are detected by the fire boss on his early morning tour and provision is made for their removal. It has not as yet been proved that these very important local accumulations are connected with increase in the total methane volume issuing from the mine or with any of the seismic or meteorological conditions. The human factor is the controlling cause of most of the accidents. Many come from carelessness in the details of ventilation, or mismanagement of lamps or fire in other form and from blown-out shots. Ordinarily there are fewer accidents during times of evident danger than when there appears to be less need of precaution and miners take more risk. With dust explosions the factors are somewhat the same and most of the catastrophes are due not to any special condition in the mine but to some careless act or mishap that would have yielded the same result at any other time.

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INDEX.

A.

Page.

- "A" mine, Ill., occurrence of gas in........ 200, 224
  - relation of depth to, figure showing.. 223
  - effect of cessation of mining on....... 219
- Abbott bed, Pa., workings in, occurrence of gas in............ 123, 127, 154, 156, 157, 167
    - effect of cessation of mining on. 145, 146
    - relation of, to output of coal...... 124
      - to coal surface exposed....... 124
  - structure of.................... 123, 124, 128
- Abel, Frederick, on blower in Wallsend colliery, England...................... 20
  - on relation of weather to gas emanation.. 82
- Abercarne mine, Wales, gas outburst in..... 22
- Acieriers de France, mine at, analysis of gas in.................................. 19
- Agrappe mine, Belgium, gas outbursts at, discussion of.......................... 22–24
  - pressure of gas in coal in................. 227
- Air pressure. *See* Atmospheric pressure.
- Albert mine, Germany, analyses of mine air in.................................. 49
  - occurrence of gas in...................... 50
- Alfred bed, France, gas pressures in......... 70, 71
- Altenwald mine, Germany, analyses of mine air in............................... 49
  - occurrence of gas in...................... 50
- Andros, S. O., air samples collected by...... 186, 189, 207
- Anzin, France, mines at, analysis of gas in.... 19
- Anthracite, escape of methane from.......... 38
  - occurrence of methane in............... 104, 105
- Anthracite mines, gas explosions in.......... 105
  - pressure of gas in........................ 170
- Arnould, M. G., on gas outbursts in coal.... 23, 35
- Ath-Gouley mine, Germany, methane emanation in......................... 59, 230
  - effect of atmospheric pressure on..... 84, 85
- Atmospheric pressure, effect of, on gas emanation...................... 82–98, 231, 232
    - at fresh coal surfaces............. 94, 95
    - curves showing............... 85, 87, 89
      - in old workings............... 92–94
- Auchincloss mine, Pa., workings in, figure showing section through............ 158
  - occurrence of gas in................ 157–159
  - structural features of............... 157, 158
- Austria, coal mines in, air from, analyses of.. 51
  - blower gas from, analysis of.......... 17
  - outflow of gas from.................... 230
  - relation of air pressure to gas emanation in................................ 90
  - *See also* various mines named.
- Austrian Fire Damp Commission, investigations of........................ 17, 53, 90
- Avondale mine, Pa., workings in, occurrence of gas in.............................. 169

B.

Page.

- "B" mine, Ill., gas pressure in, tests of.... 217, 218
  - occurrence of gas in.................... 201, 224
    - relation of depth to, figure showing.. 223
    - effect of cessation of mining on....... 219
- Baltimore bed, Pa., workings in, area of..... 131
    - occurrence of gas in. 129, 131, 133, 153–162, 164
      - effect of cessation of mining on.. 145, 147
    - structure of.......................... 128
  - *See also* Cooper bed; Bennett bed.
- Baltimore No. 5 mine, Pa., Baltimore workings in, occurrence of gas in........ 153
  - structural features of.................... 153
- Barker, Perry, on occurrence of gas in coal.. 45, 46, 221
- Barometric pressure. *See* Atmospheric pressure.
- Beard, J. T., on relation between earth movements and gas emanation.......... 99
- Beaulieusart mine, Belgium, gas outbursts in, figure showing location of...... 67
    - results of............................ 68
  - gas pressure in.......................... 227
    - curves showing....................... 68
    - tests of.............................. 67, 68
- Bedson, P. P., on gases in English coal...... 33
- Behrens, —, on effect of air pressure on gas emanation........................... 88, 89
- Belgium, coal beds in, gas outbursts in...... 22, 23
    - gas pressure in....................... 64–66
    - proportion of methane in............ 16
  - *See also* various mines named.
- Belle-Vue mine, Belgium, gas pressure in.. 64, 227
    - curves showing....................... 66
    - results of tests of................... 65, 66
      - curves showing.................. 65
- Bellevue mine, Pa., workings in, methane emanation from................. 148
- Bennett bed, Pa., workings in, analyses of air from........................ 110, 151
    - map of............................... 113
    - occurrence of gas in................. 110, 113, 118, 133, 152, 153, 164
      - effect of cessation of mining on.. 145
      - relation of, to output of coal..... 120
        - to coal surface exposed....... 120
    - structure of.......................... 128
  - *See also* Baltimore bed.
- Benton mine, Ill., gas from, analyses of...... 182
    - rate of, escape of................ 43, 44, 181
      - curve showing.................... 43
  - gas pressure in, tests of................ 216–218
      - occurrence of gas in............. 218
    - effect of cessation of mining on....... 219
    - relation of depths to, figure showing. 223
- Bertrand, C. E., on differences in coals...... 28
- Bessèges, France, gas outbursts at........... 22, 23

Page.

Bettina mine, Austria, analyses of air in 51
Big Muddy mine, Ill., occurrence of gas in 196, 197, 224
    effect of cessation of mining on 219
    relation of depth to, figure showing 223
Bituminous coal, escape of gases from 32, 38
Blackbrier mine, Ill., gas pressure in, tests of 217, 218
  occurrence of gas in 193, 224
    effect of cessation of mining on 219
    relation of depth to, figure showing 223
Blair No. 1 mine, Ill., occurrence of gas in 213, 224
    relation of depth to, figure showing 223
Blanzy, France, mine at, analysis of gas in 19
Bliss mine, Pa., workings in, gases from 160, 161
"Blower," definition of 20
  duration of 20
  origin of 20
  volume of gas given off by 20
  See also Feeder.
"Blower gas," composition of 15–17
  proportion of methane in 14, 15
Bochum, Germany, coals from, escape of gas from 47
Bockwa-Hohndorf mine, Saxony, air in, composition of 53
    volume of 53
  occurrence of gas in 58
Boldon colliery, England, gas pressure in 62
  methane emanation from 60, 75
Bonifacius mine, Germany, analysis of gas in 18
Bore holes, drilling of, to determine gas in coal 170, 171
Boudouard, O., on absorption of oxygen by coal 81
Bowkley bed, Pa., workings in, structure of 128
Brisbin mine, Pa., workings in, gas from 149
Broockman, K., on effect of air pressure on gas emanation 89
  on gases in German coal 34
Brueckenberg mine, Saxony, air in, composition of 53
    volume of 53
  methane emanation from 58
Buddle, John, on gas outbursts 25
Bureau of Mines, investigations of 11, 175
Burr C mine, Ill., occurrence of gas in 203, 224
    relation of depth to, figure showing 223
Burrell, G. A., on accuracy in methane determinations 103
  on explosibility of fire damp 15
Bush mine, Ill., occurrence of gas in 206, 224
    relation of depth to, figure showing 223

C.

C. & B. M. mine, Ill., occurrence of gas in 204
Cadman, John, on ventilation of coal mines 84
Campagnac, France, mine at, analysis of gas in 19
Cannel coal, gases in 32
Carbon dioxide, characteristics of 13, 14
  rate of escape of 44, 47
  specific gravity of 13
Carbon monoxide, characteristics of 13
Carbondale formation, Ill., coal beds in 176
  section of 176
Carterville mine, Ill., analysis of air from 202, 203
  occurrence of gas in 194, 224
  relation of depth to, figure showing 223
Castrop, Germany, mine at, analysis of gas in 18
Cayuga mine, Pa., workings in, methane emanation from 149
Celynen mine, Wales, gas pressure in 64
Chamberlin, R. T., analyses of mine gas by 16, 18, 19, 171
  on gas in coal 28, 29, 35, 36, 38, 40–42
  results of investigations by 98
Checker bed, Pa., workings in, air from, analysis of 151
      volume of 137
    occurrence of gas in 137, 138, 152, 153
Chesneau, G., on methane emanation from coal 54, 91, 99
Christopher, Ill., gas in mines near 183–184
Clark bed, Pa., workings in, gas from 149, 150, 171
Clifford mine, Ill., volume of methane from 45, 46
Coal, fresh, escape of gas from 47
  gas emanation from, factors affecting 36, 225, 231
  lump, escape of gas from 37, 38
      rate of 41
  permeability of, to gas 76
  porosity of, effect of, on methane emanation 49
  pulverized, escape of gas from 39
  weathered, volume of gas from 47
Coal bed, depth of, relation of methane emanation to 222
  pressure of gas in, method of testing 213, 214
    tube for measuring, figure showing 214
  strata overlying, permeability of, effect of, on methane emanation 222
Colp mine, Ill., occurrence of gas in 195, 224
  relation of depth to, figure showing 223
Connellsville, Pa., mine near, escape of gas from 43, 44
      curve showing 43
    gas outburst at 21
Consolidation mine, Germany, analyses of gas in 18
Cooper bed, Pa., workings in, analysis of air from 110, 151
    map of 114
    occurrence of gas in 110, 115, 118, 133, 152, 153, 164–167
      effect of cessation of mining on 145, 146
      relation of, to output of coal 120
        to coal surface exposed 120
    structure of 128
  See also Baltimore bed.
Crushing, effect of, on escape of gas from coal 36, 41, 42
Culm, definition of 170
  escape of gas from 169, 170
  utilization of 170
Cunnyngham mine, workings in, occurrence of gas in 154

D.

Darwin, G. H., on effect of air pressure on gas emanation 99
Davis mine, Ill., occurrence of gas in 187, 224
    relation of depth to, figure showing 223

Page.

- De la Beche, —, on inflammable gas in British mines 16
- De Wolf, F. W., analyses of Harrisburg coal by 179
  - on southern Illinois coal field 176
- Dechen mine, Germany, analysis of air in 49
- Delaware mine, Pa., workings in, occurrence of gas in 152, 153
    - structural features of 152
- Depth of coal, relation of, to volume of gas 225
- Dering No. 11 mine, Ill., gas from, composition of 215
  - gas pressure in, tests of 215, 216, 218
  - occurrence of gas in 188–190, 218, 224
    - effect of cessation of mining on 219
- Dering No. 11 mines, relation of depth to, figure showing 223
- Deutschland mine, Saxony, air in, composition of 53
    - volume of 53
  - methane emanation in 58
- Diamond bed, Pa., workings in, occurrence of gas in 149
- Diamond mine, workings in, occurrence of gas in (Pa.) 148, 149
    - (Scotland) 51
- Dickson mine, Pa., workings in, occurrence of gas in 148
- Dodson mine, Pa., workings in, occurrence of gas in 168
- Donetz basin, Russia, mines in, composition of air from 51
- Dorrance mine, Pa., workings in, analysis of coal from 131
    - analysis of gas from 19, 171
    - map showing 130
    - occurrence of gas in 127, 128, 129, 131, 132, 133, 134
      - effect of cessation of mining on 145–147
    - structure of 127, 128
- Dortmund, Germany, mines at, analysis of gas in 18
- Dudweiler mine, Germany, analyses of mine air in 49
- Dufrane, A., on gas outbursts in coal mines 23, 24
- Dunmore bed, Pa., workings in, analysis of coal from 142
    - collection of air samples from 139, 140
    - map of 140
    - occurrence of gas in 141, 143, 148, 149, 150, 171
      - effect of cessation of mining on 145, 147
      - relation of, to coal surface exposed 143
    - structure of 141
- Dunraven mine, South Wales, composition of blower gas in 17
- Duquoin, Ill., gas in mines near 185–187

E.

- Earthquakes, relation of, to gas emanation 98, 99
    - curves showing 100, 101
- East mine, Ill. *See* Standard mine, Ill.
- Eldorado, Ill., mines near, analysis of air from 210, 211
- Eleven-foot bed, Pa., workings in, gas from 163, 172

Page.

- England, coal samples from, gases from 32, 33, 34
  - *See also* various mines named.
- Eppleton colliery, England, gas pressure in 62
  - occurrence of gas in 75
- Essen, Germany, mine at, analysis of gas in 18
- Ethane, escape of, from coal 47
- Explosions in mines, causes of 232

F.

- Faulting, effects of, on emanation of methane 222
- "Feeder," composition of gas from 15, 16
  - definition of 20
  - *See also* Blower.
- Fire damp, composition of 14
  - explosions of, causes of 173
    - fatalities from 173, 174
  - explosive, limits of, factors governing 15
  - properties of 15
- Five-foot bed, workings in, analyses of air from 110
    - map of 115
    - occurrence of gas in 110, 116, 129, 132, 133, 152, 153
      - effect of cessation of mining on 145, 146, 147
      - relation of, to output of coal 120
        - to coal surface exposed 120
    - structure of 128
- Floor, settling of, effect of, on gas emanation 95
- Fontenille, tests of French coal by 34
- Force, H. J., mine-air samples collected by 158, 161, 169
- Forge bed, Pa., workings in, gases from 158, 160–162
- France, coal mines in, outflow of gas from 16, 230
  - *See also* various mines named.
- Frederic bed, France, gas pressures in 70
- Friedenshoffnung mine, Germany, occurrence of gas in 50
- Friedrichsthal mine, Germany, analyses of mine air in 49

G.

- Gabrielle mine, Austria, analyses of air in 51
  - methane emanation in, effect of atmospheric pressure on 86, 87
    - variations in 88
- Galatia mine, Ill., occurrence of gas in 207, 224
    - relation of depth to, figure showing 223
- Galloway, William, on barometric changes in coal mines 83, 84
- Garwood mine, England, blower in 20, 21
- Gas in coal, composition of 225, 226
    - variation in 226
  - emanation of, effect of removal of coal on 95
    - effect of temperature on 97, 98
    - factors governing 19, 20, 226
    - relation of, to atmospheric pressure 82
      - curves showing 85, 87
      - to earth tremors, curves showing 100, 101
      - to variations in air pressure 231, 232
    - variations in conditions determining 97
  - volume of, conditions governing 225, 228, 229
    - determination of 73–75

Page.

Gas in coal, volume of, relation of, to temperature........ 80
  variations in........ 12,228
Gas pressure in coal beds, effect of rock pressure on........ 75,76
  effect of water pressure on........ 75,76
  measurement of, tube for, figure showing........ 214
  method of testing........ 213,214
  variation of........ 60,61,227,228
    causes of........ 63
    figure showing........ 63
  See also various mines and coal beds named.
Gaseous mine, definition of........ 48
Gateshead colliery, England, analyses of gas in........ 16
Gemeinschaft mine, Germany, outflow of gas from........ 54,59,230
  effect of atmospheric pressure in..... 84,85
  variations in........ 59
George bed, Pa., mine workings in, gases from........ 162
Georges Creek district, Md., escape of air through coal bed at........ 77
Germany, coal samples from, determination of gases in........ 33,34
  See also various mines and beds named.
Ghysen, Henri, on gas pressure in coal. 66,67,69,227
  on tests of French coal........ 34
Glückhilf colliery, Austria, analysis of gas in.. 17
Gouley-Gemeinschaft-Konigsgrübe mine, Germany, volume of methane from.... 50
Grassy Island mine, Pa., workings in, gas from........ 149,150
Gray, Samuel, on gas outburst at Otto colliery, Pa........ 21
Gray, Thomas, analyses of air in Scotch mines 51
Green Ridge mine, Pa., workings in, methane emanation from........ 148

H.

H. Larisch mine, Austria, analyses of air in.. 51
Hainichen mine, Saxony, air in, composition of........ 53
  volume of........ 53
  occurrence of gas in........ 58
Haldane, John, on oxidation of coal........ 80,81
  on properties of methane........ 13
Hallidayboro mine, Ill., occurrence of gas in........ 206,207,224
  relation of depth to, figure showing.. 223
Hanna, Wyo., coal from, escape of gas from, curve showing........ 43
  rate of........ 44
Hannaford mine, Ill., occurrence of gas in.. 182,224
  relation of depth to, figure showing.. 223
Hanover mine, Germany, effect of air pressure in........ 89,90
Harrisburg, Ill., coal from, escape of gas from. 43,44
  curve showing........ 43
Harrisburg bed, Ill., analysis of coal from.... 179
  features of........ 177
  occurrence of gas in........ 207-212
Harrison mine, Ill., occurrence of gas in.... 212,224
  relation of depth to, figure showing.. 223

Page.

Harry E. mine, Pa., workings in, occurrence of gas in........ 163
Harton colliery, England, gas pressure in.... 62
Hart-Williams mine, Ill., analyses of gas from 222
  gas pressure in, tests of........ 215,218
  occurrence of gas in........ 180,218,220,221,224
    relation of depth to, figure showing.. 223
Hebburn colliery, England, analyses of gas in. 16
Heinitz mine, Germany, analyses of mine air in........ 49
  methane emanation from........ 50
Heise, —, on effect of air pressure on gas emanation........ 89
Hemlock mine, Ill., occurrence of gas in. 197,198,224
  effect of cessation of mining on....... 219
  relation of depth to, figure showing.. 223
Herbst, —, on effect of air pressure on gas emanation........ 89
Herin mine, France, volume of methane from. 54,91
Herne, Germany, mine at, analysis of gas in.. 18
Herrin, Ill., mines near, analyses of air from........ 197-202,205
Herrin bed, Ill., analyses of coal from........ 178
  features of........ 176
  workings in, occurrence of gas in...... 180-207
Hetton colliery, England, gas pressure in.... 62
Hillman bed, Pa., workings in, analyses of air from........ 110,151
  map showing........ 117
  occurrence of gas in... 110,117,118,123,125,126,129,133,154-158,161,162,164,168,171
    effect of cessation of mining on.. 145-147
    relation of, to output of coal...... 126
      to coal surface exposed.... 120,126
  structural features of........ 125,126
Hilt, C., on atmospheric pressure in coal mines. 84,85
  on variations in methane emanation.. 54,58,59
Holden mine, Pa., occurrence of gas in...... 171
Hollenback mine, Pa., occurrence of gas in.. 155,156
  structural features of........ 154,155
Höngen, Germany, mine at, analysis of gas in. 18
Horn mine, Ill., occurrence of gas in........ 187,188
  relation of depth to, figure showing.. 223
Hoyt mine, Pa., workings in, air current in. 136,137
  map of........ 135
  occurrence of gas in........ 136,137
    effect of cessation of mining on.. 145,147
  structural features of........ 134

I.

Ichon, —, on gas outbursts at Bessèges, France........ 22,23
Illinois, coal beds of, extent of........ 175
  structure of........ 175
Illinois, southern, coal beds of........ 176
    structure of........ 175,176,177,178
      map of........ 178
  mines in, occurrence of gas in...... 179,180
  See also various mines named.
Illinois State Geological Survey, cooperative agreement with........ 175
Inkerman, Pa., mine workings near, gas from. 150

J.

Jarrow colliery, England, analyses of gas in.. 16
  gas outburst at, figure showing........ 25
Johnston City, Pa., gas in mines near...... 191-194

K.

Page.

- Karwin, Austria, mine at, proportion of methane in 17
- Karwin-Ostrau district, Austria, mines in, composition of air from 51
  - gas pressures in 73
- Kidney bed, Pa., mine workings in, analysis of air from 151
  - occurrence of gas in 129, 154–157, 164, 167
- Kingston No. 4 mine, Pa., occurrence of gas in 165, 166
- Knickerbocker mine, Pa., gas outburst at 21
- Koehler, G., on effect of air pressure in mines 86–88
- Kohlscheid mines, Austria, gas emanation in, effect of air pressure in 88
- Konig mine, Germany, analysis of gas in 18
- Kotsowsky, N., on analyses of mine air in Russian mines 51
- Kreuzgräben mine, Germany, analysis of gas in 18

L.

- Lance mine, Pa., coal beds at, figure showing section of 108
  - structure of 108, 109
  - thickness of 109
  - cross section of, figure showing 109
  - river deposits above, map showing 121
  - gas from, effect of river deposits on 121, 122
    - pressure of 170, 171
  - maps of 112–115, 117
  - occurrence of gas in 110, 115–120, 165, 166, 229
    - effect of cessation of mining on 145, 146
    - relation of, to output of coal 120
      - to coal surface exposed 120
  - return air from, analyses of 110
- Lange, C., experiments by 102
- Langendreer, Germany, mine at, analysis of gas in 18
- Le Chatelier, on effect of air pressure on gas emanation 86, 90, 91
  - on gases in coal 16
- Le Grande-Combe, France, mines at, analysis of gas in 19
- Lebanon mine, Ill., volume of methane from 45
- Lecocq, tests of French coal by 34
- Lemaire, E., on gas outbursts in Belgian mines 23, 24
- Leonard bed, Liévin mine, pressure of gas in 71, 72
- Liévin mine, France, gas in, sources of 78, 79
  - gas pressure in 69–72, 74, 227
  - occurrence of gas in 56, 96
    - curves showing 93
    - relation of air pressure to 91, 92
- Liveing, tests of, to determine methane emanation 60
- Lombard, —, on gas outbursts at Bessèges, France 22, 23
- Lothringen mine, Germany, analysis of gas in 18
- Lugan mine, Saxony, composition of mine air in 53
  - methane emanation in 53, 58
- Luzerne, Pa., mine gas from hole near, analysis of 18

M.

- McConnell, W., on gases in English coal 33
- McLeansboro formation, Illinois, structure of 176
- Madison mines, Ill., occurrence of gas in 203, 224
  - relation of depth to, figure showing 223

Page.

- Mahanoy City, Pa., mine near, gas outburst at 21
- Majestic mine, Ill., occurrence of gas in 187, 224
  - relation of depth to, figure showing 223
- Mallard, E., on atmospheric pressure in coal mines 86
  - on gas pressures in coal mines 63, 71, 228
- Mansfield mine, Pa., coal from, escape of gas from 38
- Manville mine, Pa., gas from workings in 149
- Maquet, A., on gas pressure in coal mines 62, 64, 67, 69
- Marchienne mine, Belgium, methane in 29
- Marcinelle-Nord mine, Belgium, gas outburst in 24
  - pressure of gas in 61
  - tests of coal from 34, 35
- Marcy bed, Pa., gas from workings in 150
- Maria mine, Höngen, Germany, analysis of gas in 18
- Marion, Ill., mines near, analyses of air from 194–197
- "Marsh gas," origin of 12
  - *See also* Methane.
- Marsilly, —, on volume of gas from coal 35
- Marvine mine, Pa., occurrence of gas in 148
- Maxwell mine, Pa., workings in, gas pressure in 170
  - occurrence of gas in 156, 157
- Mayer, Joh., on relation between atmospheric pressure and gas emanation 86
- Meachem, F. G., on oxidation of coal 80, 81
- Merthyr Vale mine, Wales, gas pressure in 64
- Metamorphism of coal, effect of, on class of coal 28
  - on methane content of coal 27, 28
- Methane, characteristics of 13
  - composition of 13
  - determination of, probable error in 103
  - emanation of, from coal 47
    - curves showing 40
    - duration of 101
    - effect of cessation of mining on 58, 59, 145–147
    - effect of porosity of coal on 49
    - effect of river deposits on 121
    - rate of 44
    - relation of, to coal area exposed 54, 56, 57
      - to depth of coal bed 222
      - to kind of mining 55
    - variation in 229
      - conditions governing 60
    - from culm 169, 170
  - in coal, amount of, relation of, to character of coal 102
    - condition of 28, 29
    - diffusion of, conditions governing 31
    - effect of metamorphism on 27, 28
    - origin of 26, 27, 231
    - processes in formation of 26, 27
    - volume of, to coal surface exposed 55
  - in return air, proportion of, conditions governing 48
  - proportion of, to output of coal 52
  - relation of, to age of coal 29
    - to depth of coal 29
    - to metamorphism 27, 28
    - to structure of coal 30
    - to tightness of cover 29, 31

Page.

Methane, specific gravity of 13
See also various mines and coal beds named.
Mills bed, Pa., occurrence of gas in 158–162
Milne, J., on effect of earth movements on gas emanation 99
Mine air, samples of, method of collecting 107, 108
See also various mines named.
Mine workings, size of, relation of, to volume of gas 225
See also various mines and beds named.
Mining, cessation of, effect of, on methane emanation 145–147, 219
Monceau-Bayemont mine, Belgium, methane in 29
Monongah, W. Va., coal from, escape of gas from, curve showing 43
rate of 44
volume of 36–39, 43
Morin, León, on methane emanation in Liévin mine 56, 57, 78, 79
on percentage of methane in lump coal 39
on relation between air pressure and gas emanation 91, 92, 95
tests of, on gas pressures in coal 71, 72, 227
Morrissey, B. C., gas outburst in mine at 22
Murphysboro bed, Ill., coal from, analyses of 179
features of 177
occurrence of gas in 212, 213
volume of gas in 212, 213

N.

Nanticoke, Pa., escape of gas from strata near 77
Nanticoke mine, Pa., coal from, escape of gas from 36, 38
Naomi mine, Pa., coal from, escape of gas from 38
Nasse, V. H., on air pressure in coal mines 84
Neu Iserlohn mine, Germany, analysis of gas in 18
occurrence of gas in 50
Neunkirchen, Germany, diffusion of methane in mine at 31, 32
New Virginia mine, Ill., occurrence of gas in 193, 194, 224
relation of depth to, figure showing 223
Nigger Hill mine, Ill., occurrence of gas in 224
relation of depth to, figure showing 223
Nitrogen, escape of, from coal 47
proportion of, in mine gases 14
Nottingham mine, Pa., occurrence of gas in 168, 169
No. 7 mine, Ill., occurrence of gas in 205
effect of cessation of mining on 219
No. 8 mine, Herrin, Ill., occurrence of gas in 204
No. 9 mine, Murphysboro, Ill., occurrence of gas in 212
Oak Ridge mine, Ill., occurrence of gas in 224
relation of depth to, figure showing 223

O.

Oberhohndorf mine, Saxony, air in, composition of 53
volume of 53
methane emanation in 58
Obernkirchen, Germany, coal bed at, analysis of gas from 18, 34
methane in 31

Page.

O'Fallon mine, Ill., volume of methane from 45
O'Gara mines, Ill., occurrence of gas in 207–211, 220, 221, 224
relation of depth to, figure showing 223
Orchard bed, Pa., workings in, gas from 165, 166, 168
Otto colliery, Pa., gas outburst at 21
Outbursts, gas, causes of 20–22, 25
effect of, on methane emanation 48
Oxidation of coal, effect of, on methane emanation 46, 47
result of 80
Oxygen, absorption of, by coal 81
escape of, from coal 47
proportion of, in mine gases 14
Ovitz, F. K., on absorption of oxygen by coal 81
on escape of gas from coal 42, 220

P.

Paintsville, Ky., coal from, escape of gas from 43, 44
Pancoast mine, Pa., occurrence of air in 148, 171
Paradise mine, Ill., analysis of air in 186
occurrence of gas in 186, 224
effect of cessation of mining on 219
relation of depth to, figure showing 223
structural features of 186
Parr, S. W., analysis of Herrin coal by 178
on escape of gas from coal 46
on gases in Illinois coals 45
Peabody mine, Ill., occurrence of gas in 45, 46, 195, 196, 224
relation of depth to, figure showing 223
Pelham mine, England, blower in, gas from 20
Pennsylvania, northern anthracite basin of, coal beds in, figure showing 106
gases in 12
gas explosions in 105
mines in, number of 105
volume of air in 105
miners employed in 105
production of coal in 106
structure of 106
view of 106
See also various mines and coal beds named.
Petit, M. P., on gas pressures in coal 72, 73
Pettebone mine, Pa., structural features of 164
occurrence of gas in 164
Pine Ridge mine, Pa., structural features of 150, 151
workings in, analysis of air from 151
Pittsburgh bed, Pa., workings in, gas from 172
Pittston, Pa., mine workings near, air current in 137
analysis of coal from 139
methane emanation from 137, 138
Pittston bed, Pa., workings in, analysis of coal from 139
occurrence of gas in 137, 138, 163
volume of air in 137
Plat-de-Gier, France, mine at, analysis of gas in 19
Playfair, Lyon, on inflammable gas in British mines 16
Plymouth No. 2 mine, Pa., occurrence of gas in 167
Pocahontas, Va., coal sample from, escape of gas from 43, 44
curve showing 43

Page.

- Poirier mine, Belgium, methane in.......... 29
- Poleck, —, on gas in Glückhilf colliery, Austria.......... 17
- Pond Creek mine, Ill., occurrence of gas in. 201, 224
  - relation of depth to, figure showing.. 223
- Porter, H. C., on absorption of oxygen by coal.......... 81
  - on escape of gas from coal.......... 42, 220
- Possum Ridge mine, Ill., occurrence of gas in.......... 202, 224
  - relation of depth to, figure showing.. 223
- Pottsville, Pa., mine near, gas outburst at... 21
- Pressure. *See* air pressure; gas pressure; rock pressure; water pressure.
- Produits colliery, Belgium, gas outburst at.. 24
- Prussia, coal mines in, analyses of gas in 18
  - outflow of gas from.......... 229
  - *See also* various mines named.
- Prussia commission, results of investigations of.......... 54
- Putrefaction, effect of, on methane content in coal.......... 26, 27

R.

- Randolph, B. S., on escape of air through strata.......... 77
- Red Ash bed, Pa., workings in, analysis of air from.......... 110, 111, 131, 151
  - map of.......... 111, 130, 135
  - occurrence of gas in.......... 110, 111, 119, 129, 133, 136, 137, 153, 155–157, 160–169
    - effect of cessation of mining on. 145–147
    - relation of, to output of coal..... 120
      - to coal surface exposed...... 120
  - structure of.......... 111, 128
  - volume of air in.......... 136, 137
- Reden mine, Germany, analyses of mine air in 49
- Redmayne, R. A. S., on atmospheric pressure in coal mines.......... 84
- Renault, B., on differences in coals.......... 28
  - on origin of methane in coal.......... 26, 27
- Rend No. 2 mine, Ill., occurrence of gas in.. 202, 224
  - relation of depth to, figure showing.. 223
- Rikowsky mines, Russia, variation of methane in.......... 51
- Roberti-Lintermans, Frederic, on gas outbursts in Belgian coal fields.......... 23, 24
- Rock bed, Pa., workings in, gas from.......... 149
- Rock pressure, effect of, on gas pressure..... 75
- Rock Springs, Wyo., coal from, escape of gas from.......... 43, 44
- Rocks, permeability of, to gas.......... 76
- Roof, fall of, as cause of gas outburst.......... 25
  - settling of, effect of, on gas emanation.... 95
- Roslyn, Wash., mine at, analyses of air from. 172
- Ross bed, Pa., workings in, analyses of air from.......... 110
  - gas pressure at.......... 170
  - map of.......... 112
  - occurrence of gas in.......... 110, 112, 119, 152, 153, 155–163, 168, 169
    - effect of cessation of mining on. 145, 146
    - relation of, to output of coal...... 120
      - to coal surface exposed...... 120
  - structure of.......... 128
- Rossitz, Austria, gas pressures at.......... 73
- Rouchamp mine, France, analyses of gas in.. 19
  - volume of methane from.......... 54
- Royalton mine, Ill., occurrence of gas in.... 206, 224
  - relation of depth to, figure showing.. 223
- Russia, mines in, analyses of air from.......... 51
  - *See also* various mines named.
- Ryhope mine, England, gases in coal from... 33

S.

- Saarbrücken basin, Germany, mines at, analyses of gas from.......... 18, 34
  - composition of mine air from.......... 49
  - volume of methane from.......... 35, 52, 229
- Sacré Madame mine, Belgium, methane in.. 29
- Saint Étienne, France, mine at, gas from, analysis of.......... 19
  - volume of.......... 73, 230
  - gas pressure in coal in.......... 72, 73, 227
- Salzbach mine, Germany, analyses of mine air in.......... 49
  - volume of methane from.......... 50
- Sandstone in coal mines, gas in.......... 78–80
  - composition of.......... 80
- Sangamon mine, Ill., volume of methane from 45, 46
- Savage, T. E., analysis of coal by.......... 178
  - on southern Illinois coal field.......... 176
- Saxony, mines in, methane emanation from.. 52, 53
  - *See also* various mines named.
- Schalke, Germany, mine at, analysis of gas in. 18
- Schaumburg mine, Germany, analysis of gas in.......... 18
- Schaumburger mine, Germany, volume of methane from.......... 50
- Schloesing, T., analyses of gas by.......... 19
- Schöndorff, A., on atmospheric pressure in coal mines.......... 84
  - on gases in Prussian mines.......... 17, 49
- Schorn, G., on gas pressure in coal beds..... 63, 64
- Scotland, mines in, analyses of air from...... 51
- Scranton mine, Ill., occurrence of gas in.... 195, 224
  - relation of depth to, figure showing...... 223
- Seibert, F. A., on explosibility of fire damp.. 15
- Semibituminous coal, gases in.......... 32
- Shale in coal mines, gas in.......... 78
- Shamrock mine, Germany, analysis of gas in. 18
- Shaw, E. W., analysis of coal by.......... 178
  - on southern Illinois coal field.......... 176
- Sheridan, Wyo., coal from, escape of gas from. 43, 44
  - curve showing.......... 43
- Silesia, gases in coal from.......... 34
- Simon, A., on gas in Liévin mine.......... 78
  - on pressure of gas in coal.......... 69, 70, 227
  - on volume of gas from coal.......... 74
- Skidmore bed, Pa., mine workings in, gas from.......... 164
- "Slate," impenetrability of.......... 77
- Sloan mine, Pa., workings in, analysis of coal from.......... 142
  - collection of air samples from...... 139, 140
  - map of.......... 140
  - occurrence of gas in.......... 141, 143
    - effect of cessation of mining on. 145, 147
    - relation of, to coal surface exposed 143
  - structure of.......... 141
- Smethurst, W., on blower in Garwood mine, England.......... 20

Page.
Smith, H. I., mine-air samples collected by.. 104, 109, 125, 128, 151, 152, 155
Snake River bed, Pa., gas from mine workings in. 167
South Wilkes-Barre mine, Pa., workings in, analyses of return air from. 123
occurrence of gas in. 123, 125, 126
effect of cessation of mining on. 145, 146
relation of, to output of coal. 124, 126
to coal surface exposed. 124, 126
structural features of. 122–124
Spalding, W. A., on earth movements and gas emanation. 99
Squeeze, as cause of gas outburst. 26
definition of. 26
effect of, on methane emanation. 48
Squirrel Ridge mine, Ill., volume of methane from. 45–47
Stainier, X., on relation of methane to depth of coal. 30
Standard mine, Ill., occurrence of gas in. 224
effect of cessation of mining on. 219
relation of depth to, figure showing.. 223
Stanton bed, Pa., workings in, occurrence of gas in. 123, 155, 156, 167, 170, 171
Stassart, Simon, on gas outbursts in Belgian mines. 23, 24
Stevens mine, Pa., results of squeeze at. 26
Storrs mine, Pa., workings in, methane emanation from. 149
Stow, A. H., on earth movements and gas emanation. 99
Sun spots, effect of, on gas emanation. 98, 99
Sunnyside mine, Ill., occurrence of gas in.. 199, 224
relation of depth to, figure showing.. 223

T.

Taylor mines, Ill., occurrence of gas in. 198, 199, 224
effect of cessation of mining on. 219
relation of depth to, figure showing.. 223
Temperature, effect of, on gas emanation. 12, 97, 98, 230
increase of, from oxidation. 80
Thomas, J. W., on gases in coal. 32
on methane emanation in coal mines. 54
Tremonia mine, Germany, analysis of gas in.. 18
Truesdale mine, Pa., occurrence of gas in.. 161, 162
Twin bed, Pa., workings in, gases from. 160, 162

U.

United mine, Ill., composition of gas from. 183
gas pressure in, test of. 216, 218
occurrence of gas in. 183, 224
relation of depth to, figure showing.. 223
United States Geological Survey, investigations of. 11
University of Illinois, cooperative agreement with. 175
Usine pit, Russia, occurrence of gas in. 51

V.

Van Arnim mine, Saxony, air in, composition of. 53
volume of. 53
methane emanation in. 58
Van der Heydt mine, Germany, analyses of mine air in. 49
methane emanation from. 50

Page.
Von Burgks mine, Saxony, air in, composition of. 53
volume of. 53
methane emanation in. 58
Von Meyer, E., on escape of gas from coal. 46

W.

Wabner, Robert, on atmospheric pressure in coal mines. 84
Waldenburg, Germany, mine at, analysis of gas in. 18
Wales, coal beds in, gas pressure in. 64
Wallsend colliery, England, analysis of gas in. 16
gas from blower in. 20
Warrior Run mine, Pa., results of squeeze at. 26
Water pressure, effect of, on gas pressure in coal. 75, 76
Watteyne, V., on gas pressure in coal beds.. 63, 64
Wellesmeiler, Germany, blower in mine at. 20
West Frankfort, Ill., mines near, occurrence of gas in. 188–191
West mine, Ill., occurrence of gas in. 192, 224
West Virginia mine, Ill., occurrence of gas in. 195, 224
relation of depth to, figure showing.. 223
Westphalia mine, Germany, coal samples from, gases in. 34
volume of methane from. 14, 50, 55
variations in. 55
Westville mine, Ill., volume of methane from. 45, 46
Whalley, E. R., on ventilation of coal mines. 84
Wilkes-Barre, Pa., escape of gas from strata near. 76, 77
mine near, analysis of gas from. 171
volume of methane from. 52, 104, 229, 230
Wilmington-Star mine, Ill., occurrence of gas in. 191, 218, 224
relation of depth to, figure showing.. 223
effect of cessation of mining on. 219
Winkler, C., on methane emanation in coal mines. 52, 58
Wood, Lindsay, on pressure of gas in coal. 61, 227, 228
on volume of gas from coal. 74, 75, 230
Wurms, Germany, mine at, relation of methane to structure of coal in. 30

Y.

Youse mines, Russia, variation of methane in. 51

Z.

Zaukeroda mine, Saxony, air in, composition of. 53
volume of. 53
methane emanation in. 58
Zeigler District mine, Ill., occurrence of gas in. 183, 184, 224
relation of depth to, figure showing.. 223
Zeigler mine, Ill., composition of gas in. 184, 185
gas pressure in, tests of. 214, 218
occurrence of gas in. 184, 185, 218, 224
effect of cessation of mining on. 219
relation of depth to, figure showing.. 223
Zollern mine, Germany, analysis of gas in. 18
Zwickau, Germany, coals from, escape of gas from. 47